

A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS
IN THE SYDNEY COALFIELDS

BY

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Department of Energy Mines and Resources
CANMET, Coal Research Laboratories
210 George Street
SYDNEY, Nova Scotia
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Attention: Dr. A.W. Stokes
Scientific Authority

Dear Sirs:

**Re: A Review of Gateroad Sealants to Reduce Gob Leakage in
Advancing Longwall Sections in the Sydney Coalfield
DSS File # 23SQ.23440-3-9033
DSS Contract Serial # 0SQ83-00222**

We take pleasure in submitting our final report of our review of Gateroad Sealants to Reduce Gob Leakage in Advancing Longwall Sections in the Sydney Coalfield.

We would like to thank the Canada Centre for Mineral and Energy Technology, Energy Mines and Resources, Canada, for sponsoring the study and for their advice and guidance during its execution.

Respectfully submitted,

ASSOCIATED MINING CONSULTANTS LTD.

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ALC:ms

AR-73

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Central Mining Institute, Poland
Charbonnages de France, France
National Coal Board, UK
Mine Health and Safety Administration, USA
US Bureau of Mines, USA

and many manufacturers and distributors of sealants and sealing equipment.

DISCLAIMER

Proprietary names are used in the report for the purpose of identifying specific equipment or materials. Reference to a particular product does not imply endorsement by the authors or by CANMET.

The scope of the study has precluded a fully comprehensive review of equipment and materials currently available. In addition to the products identified in the report there may be others available with similar characteristics.

EXECUTIVE SUMMARY

The principal mining method employed in the Sydney Coalfield, Cape Breton Island, Nova Scotia, is longwall advancing. Long life panels are worked extracting a height of approximately 1.85 m to 2 m using shearers and powered supports. The seam is gassy and coal production rates are high. The longwalls require large air quantities at the face to dilute methane and the environment could be improved if leakage through worked-out (gob) areas could be reduced.

Three methods of leakage reduction have been applied in the Sydney Coalfield - improving the packs density by pneumatic or monolithic packing; sealing the pack edge; and reducing the ventilation pressure differential across the gob.

The study reviews sealants used in the mining industry and some from non-mining applications to determine the best sealant and application methods for the conditions prevailing in the Sydney Coalfield.

Sealants are grouped in three main categories - gypsum based, cement based and other. The last group includes sealants based on or incorporating rubber latex, urea formaldehyde, phenolic resins and bentonite.

Three sealing methods are discussed - surface application, shutter and fill and sealant blocks. Dry and wet process sealing equipment is described. Criteria for the selection of sealants are defined and the most appropriate method, equipment and material for sealing on advancing longwalls in the Sydney Coalfield are recommended.

The best technique is the construction of a block of sealant using foamed cement. Equipment, materials and procedures for this system are described.

A testing protocol for the assessment of new sealing materials is proposed and a range of test procedures are described.

SOMMAIRE

La principale méthode minière utilisée dans le champ de charbon de Sydney, Île du Cap Breton, Nouvelle-Ecosse, est l'exploitation par taille avançante chassante. Les haveuses-chargeuses à tambour et les soutènements utilisant exclusivement une énergie non-manuelle sont employés pour l'extraction d'environ 1.85 à 2 mètres dans les chambres d'une longue durée de vie. La couche est gazeuse et les taux de production sont élevés. Les longues tailles nécessitent de larges quantités d'air pour diluer le méthane et le milieu de travail serait amélioré si les fuites d'air pouvaient être réduites dans les arrière-tailles.

Trois méthodes pour contrôler les fuites d'air ont déjà été employées dans le champ de charbon de Sydney: une amélioration de la densité des 'packs' à l'aide de remblayage pneumatique ou bétonné; un étanchement du bord du 'pack'; et une réduction de la pression différentielle de ventilation à travers l'arrière-taille.

Cette étude passe en revue les agents d'étanchéité employés dans l'industrie minière et quelques autres d'usage non-minier afin de déterminer quel agent d'étanchéité et quelles méthodes d'usage seraient les mieux appropriés aux conditions générales du champ houiller de Sydney.

Les agents d'étanchéité sont groupés en trois catégories principales: ceux à base de gypse; ceux à base de ciment et ceux dont les bases sont variées. Ce dernier groupe comprend les agents d'étanchéité à base ou dont une partie de la base contient du latex de caoutchouc, de l'urée formaldéhyde, des résines de phénol et du bentonite.

Trois méthodes d'étanchéité sont ici discutées: celle utilisée à la surface, celle qui emploie des formes dans lesquelles le ciment est coulé et celle des

blocs d'agents d'étanchéité. Des procédés d'étanchement à sec ou humides y sont décrits. Les critères pour choisir des agents d'étanchéité y sont définis et on y recommande la méthode, l'équipement et les matériaux les mieux appropriés pour l'étanchement dans les tailles avançantes chassantes du champ de charbon de Sydney.

La meilleure technique est la construction d'un bloc d'agent d'étanchéité utilisant de la mousse cimentaire. L'équipement, les matériaux et les procédés à suivre pour l'emploi de ce système sont décrits dans cet exposé.

On y propose aussi un protocole de vérification pour l'évaluation des nouveaux matériaux d'étanchement en même temps qu'on y décrit une variété de procédés de vérification.

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SECTION 1 - BACKGROUND

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SECTION 1 - BACKGROUND

1.1 RATIONALE

The Sydney Coalfield is located in Cape Breton Island, Nova Scotia. The principal mining method employed is longwall advancing. Generally favourable geologic conditions enable long life panels to be worked. Panel runs have exceeded 3000 m. The seam thickness extracted is approximately 1.85 m - 2 m. The coal winning equipment works at a high level of efficiency and the major restriction on face performance is the rate at which the roadways can be advanced ('brushed'). After considerable experimentation it has been found that the most satisfactory intake gateside packing is chock wood. With this technique there is a tendency for air to short-circuit through the packs, particularly as ventilation pressures across gobs are comparatively high to promote adequate airflows at the working faces.

In order to ensure sufficient air reaches the wall to maintain satisfactory methane and airborne dust conditions, it has frequently been found necessary to undertake sealing along the gateroad side or in the pack in an effort to reduce leakage through the gob.

This study has been initiated to review sealants used in the mining industry and those used in non-mining applications, to determine the best sealant available for the conditions prevailing in the Sydney Coalfield. If a safe, effective and economic sealing system could be found, ventilation conditions at the wall could be improved.

1.2 SCOPE

The scope of work of the study as requested by DSS is:

- "1. Through literature searches, correspondence, telephone conversations and personal visits (agreed to by the Scientific Authority in advance) the suitability of various sealant materials should be investigated and summarized.
- "2. The suitability of the various sealants should be considered from the following points of view;
 - a. cost
 - b. ease of application
 - c. elasticity
 - d. adherence to wet, dusty and dry coal, coal measure strata, steel and hardwood
 - e. flammability
 - f. toxicity
 - g. stability.
- "3. In anticipation of the laboratory tests of the most promising sealants, suitable test protocol should be suggested.
- "4. Include all of the above in the final report to be provided to the Scientific Authority by February 28, 1984."

In response to this scope of work sealing methods, equipment and sealants have been reviewed and their suitability for application in the Sydney Coalfield has been assessed. A large number of manufacturers of sealant equipment and material have been approached and their products have been reviewed. The sealing method, equipment and materials that appear to be most appropriate for the conditions in the Sydney Coalfield have been identified.

In addition, a test protocol is proposed for the appraisal of any new sealant before it is adopted for general use. Suggestions are put forward for research and development work in this field.

1.3 SYDNEY COALFIELD CONDITIONS

Two mines - Lingan and No. 26 Mine - are currently exploiting the Harbour Seam by advancing longwall. Lingan is accessed by in-seam slopes from which longwall panels are developed with faces on dip and gateroads on strike. To date, thirteen longwall panels have been exploited in this mine. Current workings are 4 West, 5 West and 8 East.

No. 26 Mine is accessed by shaft and then by a horizon system giving access to in-seam dips. From these dips longwall panels are developed with faces on dip and gateroads on strike. To date 31 longwall panels have been exploited in this mine. Current workings are 14 North and 13 South.

Both mines employ mechanized longwall using double-ended ranging drum shearers operating on armoured flexible conveyors with support by chocks or shields. Roadway construction methods include conventional ripping behind the face, the half-heading system and in-line ripping. Typical roadhead configurations at Lingan and No. 26 are shown in Figures 1-1 and 1-2.

A typical intake gate at Lingan, Figure 1-1, is supported by 4.27 m x 3.05 m splayed leg arches. These arches are lagged from the crown to the shoulder with wood. A chock is provided on the low side and hardwood packs are constructed on the high side comprising 1.52 m x 1.52 m and 0.76 m x 0.76 m wood chocks. These are separated by a gap of approximately 0.46 m wide which is systematically filled with stone dust bags. The 1.52 m x 1.52 m chock is made up of approximately 60% solid wood and presents a solid face of wood to the roadway and the smaller chock, nearest the gob, comprises approximately 50% wood. The brushing is taken in the conventional position and access onto the face is under the ripping lip.

A typical intake roadway at No. 26 Mine (Figure 1-2) is supported by 4.27 m x 3.05 m splayed leg arches with wood lagging from the crown to the shoulder. The low side is taken to solid coal. The high side is supported by three 0.76 m x 0.76 m chocks comprising approximately 50% wood. As the 'half heading' system is employed the third chock, nearest the gob, is spaced to provide a travel-way ('alleyway') giving access onto the wall.

Electrical power and compressed air are available at all roadheads.

The geologic environment is generally favourable and roadway deformation is minimal. The effect of back abutment pressure can be identified, but is generally not severe. The conditions in the pack area are generally stable. The roof converges progressively back from the face line. In some circumstances the chock wood packing deforms and pushes out into the roadway, although generally the condition of the pack is relatively stable. In practice the distance between the leg of the arch and the side of the chock nearest the roadway varies between 0 and about 0.5 m. Such fluctuation is difficult to avoid since the chocks are erected at the face some distance in advance of the arch setting operation.

Ventilation is taken in on the lower (belt) level and the air passes through the face and is returned by the upper (material) level. In some cases a connection (cundy) is made between the top (material) level and the low level of the previously worked panel above (Figure 1-3). This becomes the main return for the active panel, whose top level outbye of the cundy is a second intake. Ventilation quantities entering a production district typically range between 20 m³/s and 35 m³/s. For the week ending March 2, 1984 the ventilation quantities flowing in the advancing longwall sections were as shown in Table 1-1.

Materials are supplied to the faces generally by endless rope haulages in material levels and by diesel locomotive in intake levels. Rails are laid close to each roadhead.

The mines are operated under Federal mining legislation within the jurisdiction of Labour Canada. Mining equipment and materials must meet relevant statutory requirements. Where specific Canadian standards have not been formulated, management generally employs only equipment or materials which have passed the approval processes of other major coal industries.

1.4 LEAKAGE REDUCTION

1.4.1 Methods Used

Three principal methods of leakage reduction across longwall gobs have been applied in the Sydney Coalfield. They are:

- Improving the density of the packs by pneumatic stowing or by monolithic packing.
- Sealing the pack edge by shuttering and backfilling with sealant, by filling the alleyway with sealant, by lining the pack with brattice parallel to the gateroad, by creating a solid wall of wood in the pack, by building a wall of stone dust and by surface coating the road side with sealant.
- Reducing the ventilation pressure differential across the gob (Cundy system).

These methods have been applied in a number of districts. A synopsis of leakage reduction experience in CBDC mines is given in Table 1-2.

1.4.2 Improved Pack Density

Roadway stability can be improved and leakage reduced by building solid packs. Two different approaches have been adopted. In the first, material from a Dosco DRCL machine used for the brushing has been pneumatically stowed into the pack hole. In the second, monolithic packs have been constructed using a special cement based compound (Aquapack). Both these methods have been successfully applied elsewhere in conditions similar to those encountered in the Sydney Coalfield, but neither has been extensively employed in the CBDC mines. Successful application in the Sydney Coalfield will require the resolution of a number of local operating problems. It is to be hoped that further trials with monolithic packing can be undertaken as soon as an appropriate site and circumstances can be identified since this technique could make a significant contribution to leakage reduction.

1.4.3 Sealing

In mines that are liable to spontaneous combustion, the reduction of leakage through advancing longwall gobs is critical and sealing is most commonly carried out at or adjacent to the edge of the intake roadway. A similar approach to leakage reduction has been taken in the Sydney Coalfield and a number of variants have been tried. These include:

- brattice fixed along the high side of the intake roadway or incorporated within a chock wood pack
- foam sprayed onto the pack side
- foam used to fill the 'alleyway'
- a wall of stone dust bags built between roof and floor inside a chock wood pack
- chocks constructed to form a solid wall of wood within the pack

- shotcreting in the material level, to seal the high side of the return gate pack
- cement based sealant sprayed onto the side of the chock wood pack.

Some success has been achieved with these methods. The most effective, but not totally satisfactory method appears to be stonedust bag walls within the intake pack and filling the alleyway with urea formaldehyde foam. However, because of the concerns about potential detrimental health hazards of urea formaldehyde foam, its use has been discontinued in Canada.

1.4.4 Pressure Differential Reduction

Where an active longwall is operating along the lower side of a previously mined-out panel, advantage can be taken of the old panel roadways to modify the ventilation system of the active wall so as to reduce the pressure differential across the gob. This arrangement is shown schematically in Figure 1-3. Intake air flows along the active bottom level of the working panel, through the face, returns part way along the top level and out through a connection into the bottom level of the previous panel. The material level of the active panel functions as a leakage intake. This arrangement reduces the pressure differential across the gob of the active wall from the start line to the cundy position and hence reduces leakage. In practice a series of cundys are driven at intervals during the advance of the active panel. For example, in the case of 13S in #26 Mine, three cundys have been driven to date. The first after approximately 850 m of face advance, the second after 1650 m of face advance and the third after 1850 m of face advance. This arrangement cannot be put into operation when two panels are working side by side simultaneously.

Reduction of the pressure differential across the waste is one of the most effective methods adopted to date for leakage reduction in the Sydney Coalfield. However, it limits flexibility in the sequence of working and cannot be applied in all cases.

1.5 APPROACH

The study has appraised the sealing techniques and material currently on the market or under active development, in the light of the circumstances prevailing at the mines in the Sydney Coalfield. The techniques and material that appear most promising have been identified. Before any trial installation there must be, however, careful detailed planning in the light of specific circumstances at a selected site.

If a trial proceeds, the assistance of the manufacturers of the equipment and materials should be obtained and the trial should be directed by a senior member of the management team. The benefits of a successful trial could be far-reaching in terms both of safety and operating efficiency.

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TABLE 1-1
A DETAILED REVIEW OF GATEROAD SEALANTS
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AIR QUANTITIES - ADVANCING LONGWALLS
(Week ending March 2, 1984)

Face #	Cumulative Panel Advance (m)	Air Quantity Intake Outbye End (m ³ /s)	Air Quantity Return Inbye End (m ³ /s)
Lingan Mine			
4W	1 251	30.2	15.3
5W	56	20.3	20.0
8E	663	32.0	19.8
#26 Mine			
13S*	2 463	30.3	18.5
13N	625	30.3**	20.4

* Cundy system in use

** Measured at return (outbye end)

TABLE 1-2
A DETAILED REVIEW OF GATEROAD SEALANTS
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PARTIAL LISTING OF LEAKAGE REDUCTION EXPERIENCE - CBDC MINES

Technique	Mine	Applied at Longwall
Improved Pack Density		
- pneumatic stowing of DRCL debris	Lingan	4W
- Aquapack monolithic packing	Lingan	3W
Sealing		
- brattice along pack	Lingan	7E
- sealant block of urea formaldehyde foam	Lingan	4E
- shutter and fill with urea formaldehyde foam	Lingan	7E
- fill alleyway with urea formaldehyde foam	#26	12S
- solid wall of chockwood	#26	13S 14N
- stonedust bag wall	Lingan	8E
- surface coat roadside chocks with Mandoseal	Lingan	8E
Pressure Differential Reduction		
- cundy system	Lingan #26	7E 12N 13N 13S

FIGURE 1-1
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
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TYPICAL INTAKE ROADWAY ARRANGEMENTS - LINGAN MINE

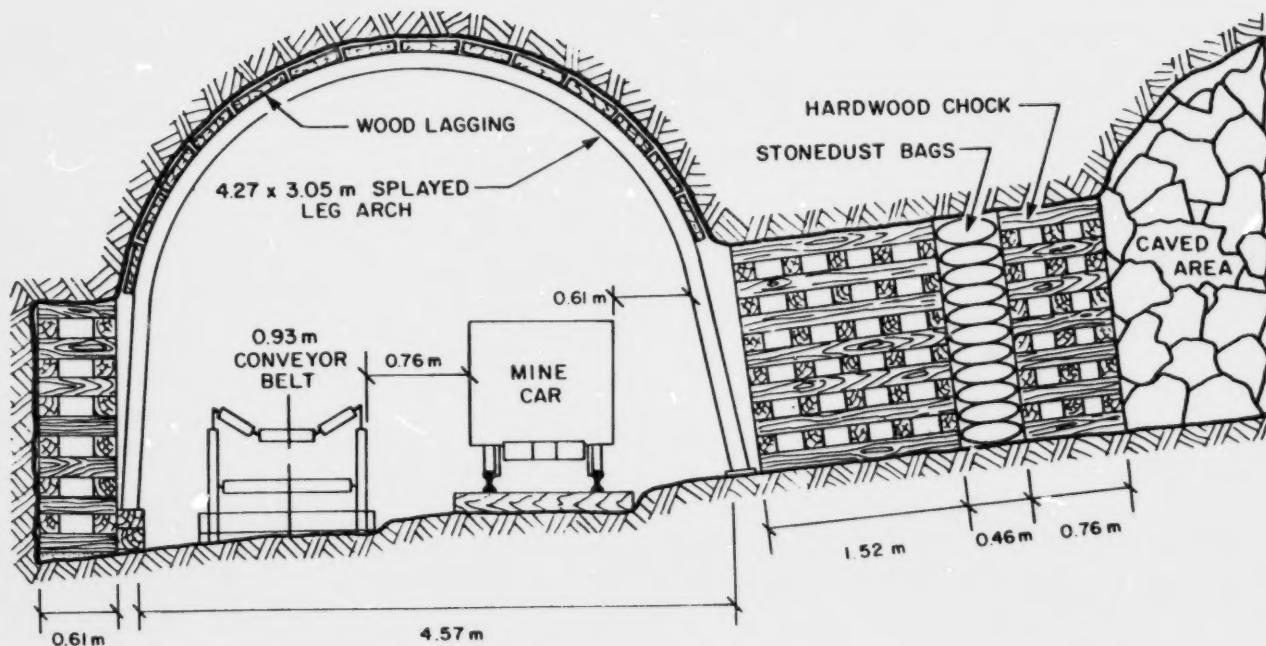
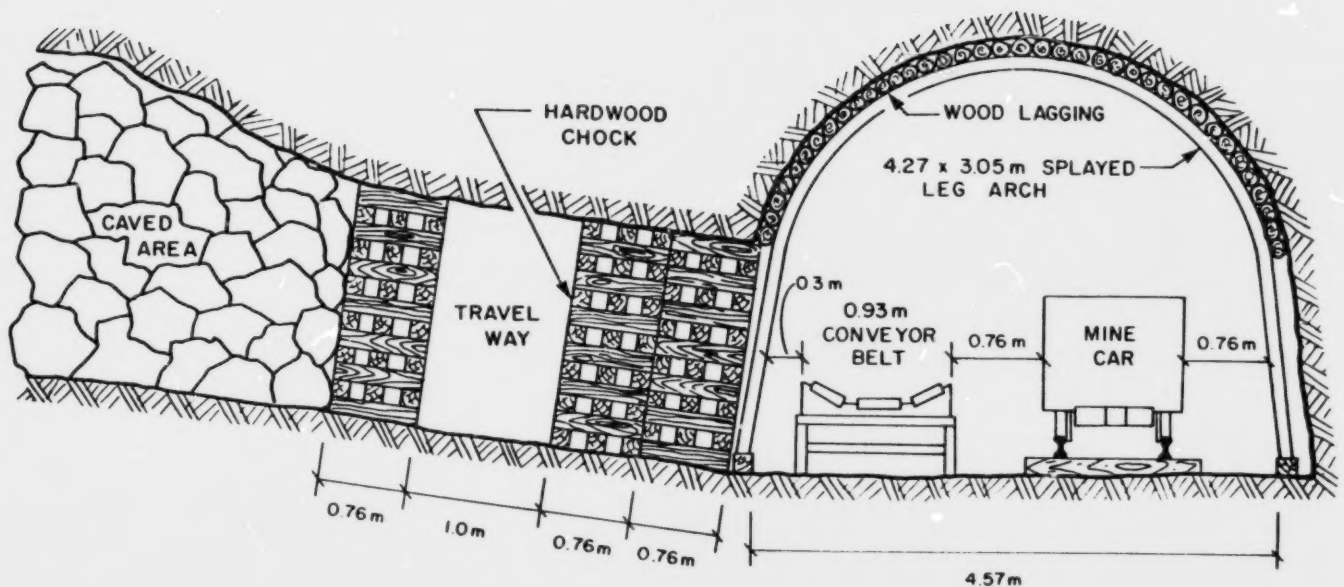


FIGURE 1-2
A DETAILED REVIEW OF GATEROAD SEALANTS
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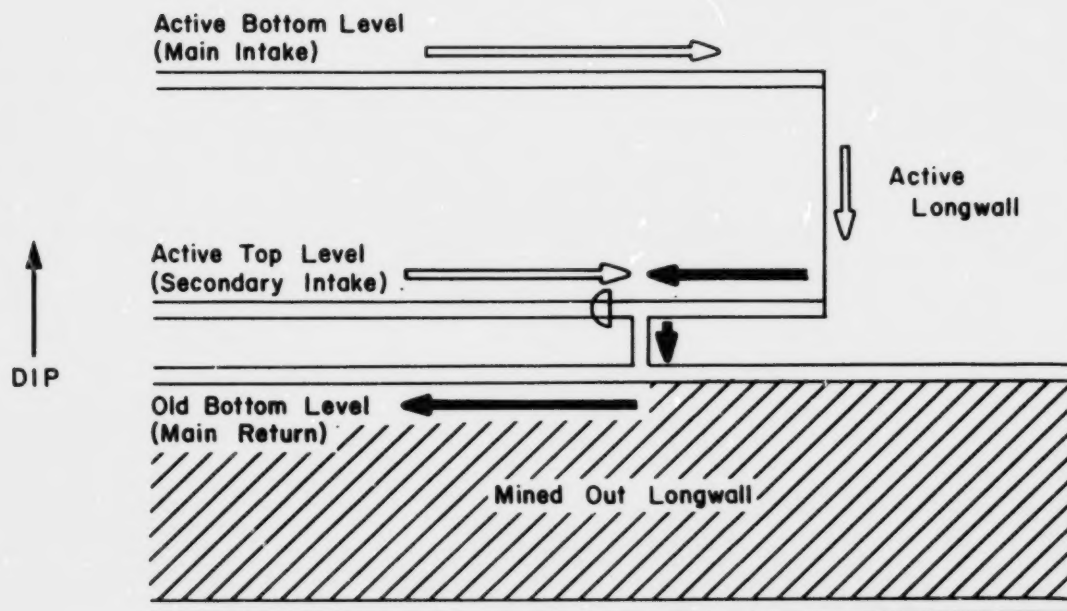
TYPICAL INTAKE ROADWAY ARRANGEMENT - #26 MINE



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FIGURE 1-3
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
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SCHEMATIC OF CUNDY SYSTEM



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SECTION 2 - SEALANT METHODS, EQUIPMENT AND MATERIALS

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SECTION 2 - SEALANT METHODS, EQUIPMENT AND MATERIALS

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(Following Text)

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SECTION 2 - SEALANT METHODS, EQUIPMENT AND MATERIALS

2.1 INTRODUCTION

In this section alternative sealing methods, sealing equipment and sealants are reviewed. Sealants are grouped into three main categories: gypsum based, cement based and other. The last group includes sealants based on, or incorporating, rubber latex, urea formaldehyde, phenolic resins and bentonite.

A large number of manufacturers produce sealants for the mining and non-mining industries. In the course of the study in excess of seventy of these companies and organizations have been approached and in most cases have responded with information on their sealing equipment and materials. Within the scope of this study it has not been possible to conduct a fully comprehensive review and to illustrate the characteristics of each class of product so typical examples have been provided. There are, of course, many other proprietary products with similar characteristics. A list of manufacturers contacted is provided in Appendix A to enable potential users to make additional enquiries about their specific requirements.

Following an appraisal of the mining conditions in the Sydney Coalfield, previous experience with sealants and a review of sealing equipment and materials available, conclusions are drawn as to the most appropriate sealing techniques for the Sydney Coalfield.

2.2 SEALING METHODS

There are three basic methods of sealing to reduce air leakage through a caved longwall gob - surface application of sealants to the gateroad

and/or pack side, shuttering the side of the roadway and filling between shuttering and the pack (shutter and fill) and construction of a sealant block in or adjacent to the pack. These three methods are discussed below.

2.2.1 Surface Application

Preparation includes filling any cavities in the pack side, scaling loose material from the strata above the pack and cleaning out at the foot of the pack to obtain a good key into the floor. Sealant can then be applied by hand trowelling or brushing or by spraying using dry or wet process machines. This type of application is illustrated in Figure 2-1. Surface application of sealant is the least effective method of leakage reduction and performance is seriously impaired by even minor strata movement.

In the circumstances prevailing at the CBDC mines it is estimated that on average approximately 0.1 m^3 of sealant will be required per metre of advance to surface coat the side of the intake pack to a thickness of 3 cm.

2.2.2 Shutter and Fill

In this technique shuttering is constructed along the roadside behind which sealant material is placed by hand or by powered equipment to form a wall between the roadway and the pack. This technique is illustrated in Figure 2-2. It is essential that shuttering is carefully constructed and extended to a height above the top of the pack. The shuttering should be keyed into the floor. The space between the shuttering and the pack wall is then filled with sealant by hand placing or by powered equipment. Though this method requires more labour and materials than surface application, it is more effective. It should only be applied

in roadways where there is minimal deformation of roadway supports and pack sides. If necessary, steps should be taken to maintain the integrity of the supports by including a yield element - for example, stilts or footings of compressible material - to enable the arches to absorb convergence of the strata without major deformation.

Typically shuttering can be constructed from 40 mm thick soft wood boards or incombustible panels precut on the surface to match the spacing between the flanges of the roadway supports. The boards or panels can be slid into position to form an effective shuttering. If necessary, brattice sheets can be inserted behind the shuttering.

The shutter and fill method requires a larger volume of sealant than surface application and a low cost sealing material or a material that can be bulked up with low cost constituents is desirable.

In the circumstances prevailing in the CBDC mines it is estimated that on average approximately 0.75 m^3 of sealant will be required per metre face advance to seal one pack edge using the shutter and fill method.

2.2.3 Sealant Block

In this method a block of sealant material generally larger in volume than in the shutter and fill method is integrated into the pack. This technique has been used previously in CBDC mines, for example, filling the alleyway with foam and constructing a wall of stone dust bags within the pack.

In this method either an alleyway or a specially constructed space in the pack is filled with sealant material as the face advances or the chock nearest the roadside is constructed so that the core can be filled from the roadway. This method of application is shown in Figure 2-3.

To construct an effective sealant block, a fairly large volume of material will be required. A low cost or bulked up sealant is desirable. Since such sealants may lack structural strength it is desirable to construct the seal after the convergence from the back abutment has been absorbed by the pack. Thus in practice a sealant block may be constructed some 50 m behind the wall. Some temporary restriction to the airflow such as a solid wall of wood or a line of brattice should be incorporated into the pack to minimize air leakage between the face and the completed sealant block.

Provided strata movement in the pack is not severe, the sealant block makes a better barrier to leakage than the shutter and fill method and is significantly more effective than surface coating.

The estimated volume of sealant material required to construct a sealant block at one end of the wall within 0.76 m x 0.76 m roadside chocks is $0.80 \text{ m}^3/\text{m}$ and for filling the alleyway or similarly dimensioned chamber is $1.5 \text{ m}^3/\text{m}$.

2.3 SEALING EQUIPMENT

2.3.1 General

Sealants can be applied by hand or mechanical methods. For hand application simple tools and mixing tanks are the only equipment required. Mechanical methods can be divided into two classes -

dry process equipment and wet process equipment. In the dry process the sealing material or mix is forced along the delivery line and mixed with water or additives at the point of application. In the wet process the sealant is mixed at the machine and forced along a delivery line as a slurry to the point of application.

2.3.2 Dry Process Equipment

The dry process equipment can be divided into two main classes - machines primarily designed for or based upon guniting techniques and machines specifically designed for mining industry use, generally to apply cement or gypsum based sealants.

The gunite type of dry process machine is exemplified by the Aliva 245. This machine is based on commercial gunite technology modified for use in mining environments. The machine is shown in Figure 2-4 and consists of a feed hopper mounted over a compressed air driven rotor which moves and feeds the material into the discharge system. Water is added at a controlled rate at the discharge nozzle. The machine is available with five different rotors for various duties. The capacity is between approximately $1.1 \text{ m}^3/\text{h}$ and $3.5 \text{ m}^3/\text{h}$. It is mounted on a tubular skid frame and approximate dimensions are 1.2 m high, 0.6 m wide and 1.2 m long. Weight is about 350 kg.

Another example of the mining dry mix gunite type machine is the Allentown Rotary Gun (Figure 2-5). The GM27 is available with electric or rotor or piston air motor drive. It can be equipped with wheels, A-frame or for fork lift mounting. Normal operating pressure is 3.8 bar to 6.0 bar with up to 33 m of hose. This pressure must be increased for additional delivery lengths. The equipment can be operated at lower pressure with certain materials. Throughput is in the range of $0.95 - 3.8 \text{ m}^3/\text{h}$.

Approximate dimensions are 1.2 m long by 0.7 m wide by 1.34 m high. Weight is 350 kg.

Special dry process machines have been developed to meet the specific circumstances of underground coal mines. They contain no light metal parts or V-belts and are skid mounted. An example is the Markham EHP (Figure 2-6), which is a compressed air driven machine requiring a minimum pressure of 3.4 bar. The loading hopper feeds a mixing device located over a rotor. As each rotor chamber passes a hole in the base of the hopper a batch of material enters. It is turned through 180° and blown by compressed air through the outlet port. Additional compressed air is added to force the material through the discharge pipe. At the end of the discharge pipe water is added at the mixing nozzle. Various rotor designs are available according to the duty and type of material handled. Maximum output is 3.4 m³/h. The compressed air driven rotor is variable speed. Approximate dimensions of the machine are 1.3 m long, 0.7 m wide and 1.1 m high (including hopper). Approximate weight is 440 kg.

In many mining applications compressed air is not available at the location where sealing is to be carried out and an all electric machine is required. This category of machine is exemplified by the Markham ELP (Figure 2-7), working with an MD400 blower. The spraying machine and blower unit comprise a portable system requiring only electrical power. The output is the same as for the Markham EHP (high pressure) machines and any dry material meeting size parameters can be handled. The dimensions of the machine are the same as the Markam EHP. The compressed air supply from the 30 kw blower is 0.12 m³/s at a gauge pressure of 1.6 bar. The electric driven rotor operates at a constant speed. Maximum throughput is 3.4 m³/h.

Another approach to dry process sealant handling is to modify equipment which is generally available in most underground coal mines for the distribution of stone dust by adapting it for the dry handling of sealants. An example is the Stratasealer nozzle mix system. A nozzle is connected to a rock duster delivery hose converting it to a sealant delivery system to which water is connected at the nozzle. This approach involves minimum capital cost and maximizes the utilization of existing equipment. It also enables sealant to be handled in bulk.

2-3-3 Wet Process Equipment

Wet process equipment can be divided into two main classes - machines primarily designed for the mixing and pumping of cement, gypsum or similar sealant slurries, and those designed for the generation and placement of resin foams.

An example of the first type is the Hunt Varimix placing machine, Figure 2-8), with a capacity of approximately 2 t/h of solid material providing about 3.8 m³/h of slurry. The sealant is placed in a hopper from which it is screw fed into the pump and at this point a metered supply of water (45 L/min to 55 L/min) is introduced. The pump is a wide throated Mono machine powered by a 7.5 kw compressed air or electric motor. The approximate dimensions of the machine are 2.0 m long, 0.5 m wide and 0.8 m high. The machine weighs 385 kg. Two or three men are required to feed the machine with sealant. It should be set up level and it is essential that a diaphragm type pressure gauge is fitted on the delivery side. The pressure should not be allowed to rise above gauge pressure of 1.7 bar. Typically the delivery is through a 10 m long 60 mm diameter hose.

Another machine of this class is the single or double hopper carousel pump exemplified by the Model 125112 distributed by BBond. This is a double hopper unit powered by an electric or air motor. The pump motor is variable speed and the mixer motor is two speed on the electric model and variable speed on the compressed air model. The unit consists of two 66 L easy-clean parabolic shaped hoppers. The mixer may be tripod mounted on top of the hopper or of the swing type. Approximate overall dimensions of the wheeled model (with mixer) is 1.7 m in. long by 0.9 m wide by 1.1 m high. The equipment weighs approximately 160 kg. These units are suitable for applications where high capacity is not essential.

The Strong Sealmaster (Figure 2-9) is a wet process machine with the mixer pump, water meter, compressor and power supply assembled into one compact unit. It has double drum mixing for increased throughput and uniform blending of slurry. It is designed specifically for underground mining operations and can be AC or DC powered or hydraulically operated off auxiliary hydraulic systems. The machine needs a two-man crew - one at the mixer and one at the nozzle.

The Langley wet process unit (Figure 2-10) is designed to mix and deliver foamed cement sealant (Aqualight). The machine is a modified two-speed placer powered by 7.5 kw, flange mounted 550/1100 V motor, incorporating a Mono type pump. The machine has two alternative delivery rates - 22 kg/min or 14 kg/min of sealant. These inputs require 22 L/min and 14 L/min of water to produce 13 m³/h or 8.8 m³/h of foamed sealant. The rate of feed of sealant can be selected by the operator and the appropriate amount is dispensed by a feed screw. A typical discharge line would comprise 25 m of 20 mm, followed by 40 m of 25 mm hose. Operation requires a two-man crew. The approximate dimensions

of the machine are 3 m long by 0.6 m wide by 0.95 m high. The unit weighs 575 kg.

Another variation of the standard placing machine made by Colcrete (Figure 2-11) is also available to handle a range of sealants including foamed gypsum and foamed cement.

Resin foams are handled in different wet process equipment from that described above. Urea formaldehyde foam, such as Igloneige, is dispensed by equipment (Figure 2-12) that consists basically of two compressed air pumps and a pistol type mixer. There are two separate intake circuits, one for the resin and the other for hardener. Each is drawn from a separate can of material. The discharge equipment consists of 30 m each of air, resin and foam producer pipe. The pistol spray gun has independent valves for resin and foam producer, an air hose, hardener rinsing, central resin injection, three chambers (pre-foaming, foaming and compression) and an injection hose. The pumping equipment weighs 26 kg and the pistol unit 4.5 kg. A two-man crew operating this equipment can produce between 10 m³/h and 15 m³/h of foam.

2.4 GYPSUM BASED SEALANTS

Sealants of this type are composed principally of gypsum generally with fillers such as perlite, vermiculite, granulated mineral wool or fiberglass added to impart higher elasticity and structural strength to the set material. In some sealants the fillers are an integral part of a prepared dry mix. In others, the fillers are introduced separately at the spray head.

Pure gypsum can set in 20 minutes or less. For that reason, practically all commercially produced sealant mixes contain additives designed to extend and control setting time. Setting times up to 90 minutes have

been achieved in this manner. Non-toxic in the wet or dry state, these materials do not present any health hazard, and no special precautions are required during application.

Application is generally with a wet process machine although the dry process has been used where the fillers are added separately at the spray nozzle. Set materials remain elastic and will indent rather than fracture when hit. Localized damage is easily repaired by applying a small mix with a brush or trowel.

Prolonged exposure to temperatures above 125°C dehydrates the gypsum component and opens shrinkage cracks causing failure of the seal. This limits their use if conditions of sustained high temperature are expected. Continuous exposure to very damp conditions can lead to softening or disintegration. Running water can cut channels in the set material.

Totally non-combustible, some mixes have exhibited excellent fire retardant properties in full-scale fire trials. Mining timber coated at a thickness of 8 mm - 10 mm has been raised to Class I performance in the Surface Spread of Flame Test (B.S. 476, Part 1, 1953).

Secondary benefits from surface coating with gypsum based sealants include greater structural strength and improved working environment through cleanliness, better accoustics, and improved lighting by reflectivity.

A modified gypsum base sealant has been developed containing a proportion of rubber latex, which gives improved elasticity and resistance to cracking.

A foamed gypsum product, Aerostem, consists primarily of gypsum with added sodium carbonate and aluminum sulphate. After wetting the

additives release carbon dioxide gas, which foams the mix to 2.2 times the volume of the same weight of a normal gypsum sealant.

Examples of this class of sealant are provided in Appendix B.

2.5 CEMENT BASED SEALANTS

The common constituent of these sealants is one of the various types of cement (e.g. Portland, Hi-Magnesia, Oxy-sulphate, etc.). Cement-based materials have been designed for a wide spectrum of specific applications. These range from very elastic sealant coatings to on-site prepared fly-ash cement mixes as a filler between shuttering and gateroad perimeter.

The characteristics of cement based sealants are determined by the intended end - structural roadway support, pack consolidation or sealant coating - and gives rise to two classes of materials.

The first class is designed primarily for use as a sealant or fire retardant coating. As in gypsum-base products, the elasticity and dimensional stability of cement-base sealant coatings derive from the presence of filler (e.g. perlite, vermiculite, etc.) in the mix. Fillers also act as a flow lubricant, thus allowing slurries to be pumped and sprayed at relatively thick consistency.

A second class of cement-base materials comprises those represented by a variety of premixed concrete formulations. These do not contain fillers, but may contain additives to speed the setting time. Although frequently described as sealant coatings, their brittle characteristics when set make them susceptible to damage when subject to slight strata movement. Strengthening with wire reinforcement will improve the performance. The principal application of this class of product is structural support. They generally fail as fire retardants because of

poor adhesion unless supported by mesh. These products can be used for the 'shutter and fill' method. However, cheaper approaches such as fly-ash cement mixes or formed products should be considered first.

Cement-based materials are alkaline and present a potential hazard in handling, dry or wet, due to skin irritation. Gloves and protective goggles should be worn. No other hazards have been identified.

Dry and wet process machines have been used in application. Elasticity of set coatings ranges from excellent (i.e. material will indent rather than fracture) to non-existent (cracks readily). Materials containing fillers (vermiculite, perlite, etc.) give the best performances. All cement-based materials are completely non-combustible. However, their fire retardant properties differ greatly. At the top of the range are specially formulated products containing fillers and additives. These have performed well enough in full-scale fire trials to be awarded Class I performance ratings in the Surface Spread of Flame Test (B.S. 476, Part 1, 1953). Others, such as gunited concrete have failed because of poor adhesion to mine timbers at fire temperatures.

Cement-based materials have greater structural strength than comparable gypsum-based mixes. They provide similar secondary benefits such as better acoustics and cleanliness. Some products contain chalk or whitener to help improve lighting by reflectivity.

A foamed cement based material (Aqualight) has recently been developed by MRDE, U.K. and is currently produced commercially for cavity filling. It has potential for use as a sealant and has many of the advantages of resin foams, without some of their disadvantages. The product is supplied as a one bag mix and is processed in a modified placing machine. During passage through the outlet hose the foaming agent in the mix becomes dispersed and fine bubbles form. The foam

emerges as an aerated gel. Gelation time is sensitive to temperature and humidity sensitive, but typically is five minutes.

This material has an expansion factor of up to about 15:1 and typically 100 kg of powder produces 1 m³ of foam. A modified mix may be produced for specific shutter and fill and sealant block applications.

Examples of this class of sealant are provided in Appendix B.

2.6 OTHER SEALANTS

2.6.1 Latex Rubber

Latex has been used on a limited scale for sealing cracks and small air spaces. It consists of neoprene latex in a water based solution which can be sprayed with most compressed air guns operating at a pressure of 3.5 bar. A coating up to 3 mm thick can be sprayed onto any surface at a single application. Since the coating cannot bridge gaps or breaks in the surface wider than 4.5 mm is necessary to fill holes beforehand with some other material. A second application is always necessary as the material develops small pin-holes as it dries. Latex can be sprayed onto wet surfaces and will adhere to any surface except dry and dusty ones.

The sprayed material and the dried surface are non-toxic and fire resistant. It is advisable, however, to work in a moving stream of air because of ammonia fumes given off during spraying. The principal advantage of rubber latex is that it will flex with moving strata but continue to maintain a seal.

Material storage to attain the recommended maximum shelf life at 6 months requires care and attention. It must be kept in

air-tight polythene containers. Storage temperature must not exceed 26°C and should not be less than 5°C. The material should never be subject to frost.

The restrictions associated with handling latex-base sealants have contributed to their limited popularity in the mining industry.

An example of this type of sealant is given in Appendix B.

2.6.2 Urea Formaldehyde

Stabilized urea-formaldehyde foam products developed in Germany and sold since 1966 under the trade name 'Isoschaum' include 'Igloneige' (France) and 'Rapco' (Canada). These materials were developed to supercede polyurethane foams that were toxic and flammable and prohibited for use in mines by the authorities in several jurisdictions.

Urea formaldehyde foam is suitable for filling between and under chocks or between shuttering and the side of the pack. Applied in this manner it has proved to be an effective barrier to leakage. The foam becomes increasingly impermeable when exposed to rock pressure. The foam is fully stabilized after about 24 hours.

Thermal stability is enhanced by adding small quantities of the same inorganic fillers (i.e. vermiculite, fly-ash, etc.) as are used in other sealant compounds.

The stabilized foam does not promote ignition or the combustion of flammable materials near it. The gases given off when in direct contact with fire contain some ammonia and are non-flammable. Many commercial fire retardants of the intumescent-barrier type are based on urea-formaldehyde

products. During fire tests it has been found that foam is not a contributing factor to the fire hazard in a mine roadway.

At present the use of this material in coal mines meets with the approval of authorities in France and Germany. Suspected long-term health problems related to urea-formaldehyde have restricted its use elsewhere.

The advantage of urea-formaldehyde foam include the small amount of material to be transported into the mine and its applicability generally without shuttering. These factors can make the process more cost-effective than many other traditional methods.

Examples of this type of sealant are provided in Appendix B.

2.6.3 Phenolic Resin

As well as urea formaldehyde products, phenolic based sealants have been developed to replace polyurethane foams. An example is Mariflex which is a two component expanding phenoplast type resin foam. The resin component is a mixture of formo-phenolic resins in a water solution. The catalyzer component is principally comprised of sulphonic acids in water solution. Mixture of both compounds at ambient temperature starts an exothermic reaction generating an inert gas which is responsible for the cellular structure of the final compound. The foam is inert and non-flammable and has been approved for use by Charbonnages de France. However, some formaldehyde gas is produced during the application of this sealant. Foam generation and placing can be carried out by a two-man crew. The expansion rate of the foam is up to 35:1, but for sealant block applications would not normally exceed about 15:1.

An example of this type of product is provided in Appendix B.

2.6.4 Bentonite

Bentonite is a naturally occurring mineral clay which swells to many times its own volume when mixed with water. When mixed, a stable jelly-like mass is formed, the gelling process being reversible if bentonite only is mixed with water. This means that when the gel is agitated it returns to the fluid state. The addition of sodium silicate restricts the gel from completely returning to the fluid state.

Bentonite is thixotropic, allowing the material to flow when pumped, but retaining its shape and position when not subject to force. Its major constituent is water. Thus a large volume of filler is obtained from a relatively small volume of materials conveyed by the mine transport system. If it comes into contact with hot material, its effect is to cool the material. The gel is stable for several months at least.

The best method of application is to mix the material alternately in two 230 L tanks containing fixed vanes interspersed with agitator paddles operated by a compressed air, electric or hydraulic motor. Thorough stirring and mixing is essential for successful application. As soon as the mixing is complete it is pumped from the tanks into boreholes in the strata, through 1 in high pressure hose, by a ram or piston pump. By this means it has been found possible to pump bentonite as far as 1650 m.

Compressed air operated pumps are better than electric pumps since the speed and pressure can be varied to suit the resistance to flow of the mixture. It is possible to inject 100 mixes per shift, producing 15 m³ of gel.

Bentonite injection is most frequently used to deal with a specific local area rather than for regular on-going of a gob area.

A summary of the characteristics of this sealant is given in Appendix B.

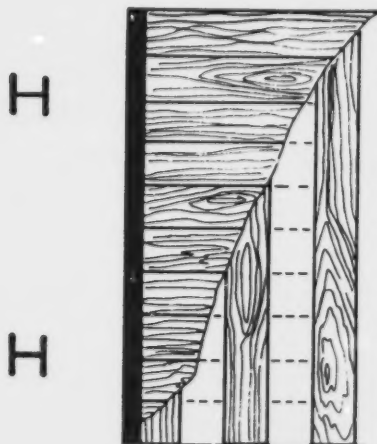
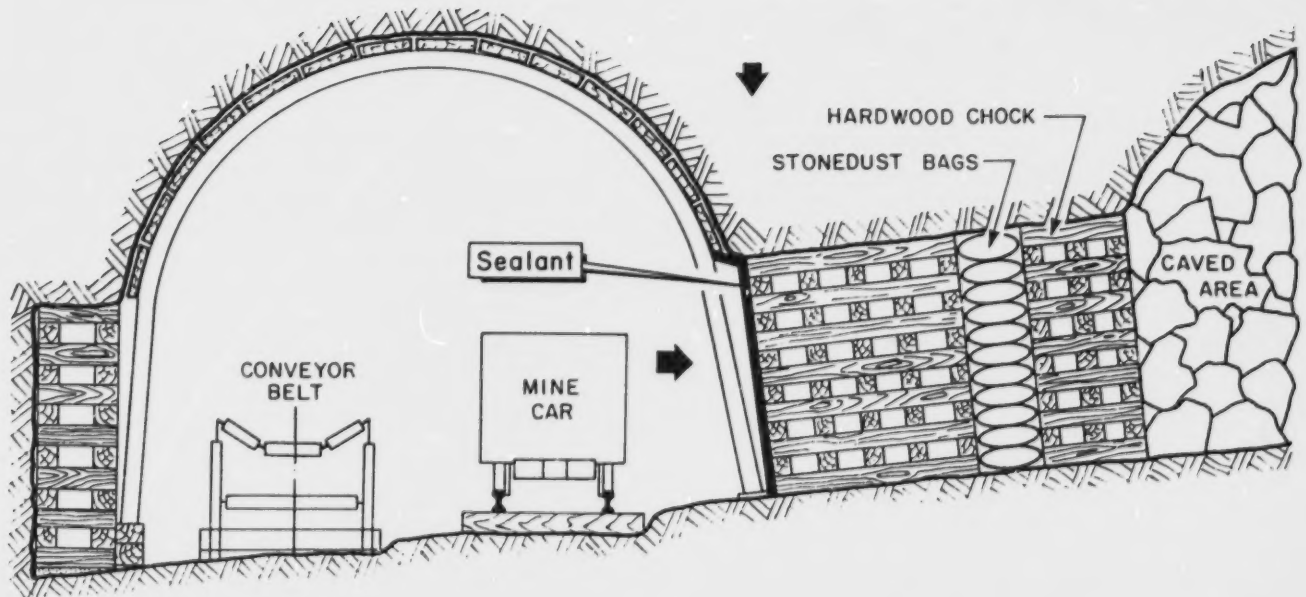
2.7 CONCLUSIONS

The most effective sealant method for the conditions in the Sydney Coalfield is the sealant block. This method required 0.8 m^3 - 1.5 m^3 of sealant in place per metre of face advance and a relatively low cost sealant material which involves minimum transportation to the wall is most suitable. Thus candidate sealants are those which are bulked up in volume by foaming. Candidate products are discussed in Section 3.

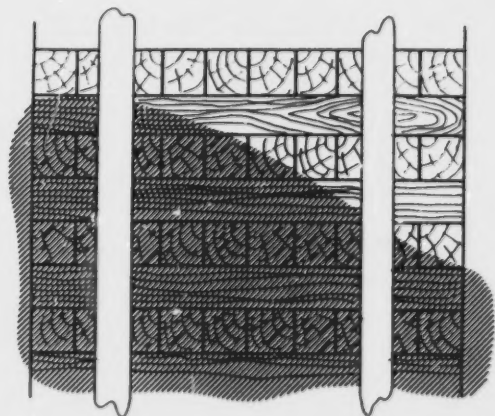
AR-73

FIGURE 2-1
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

SURFACE APPLICATION



TOP VIEW

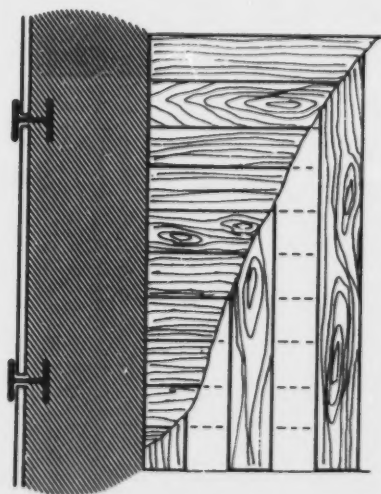
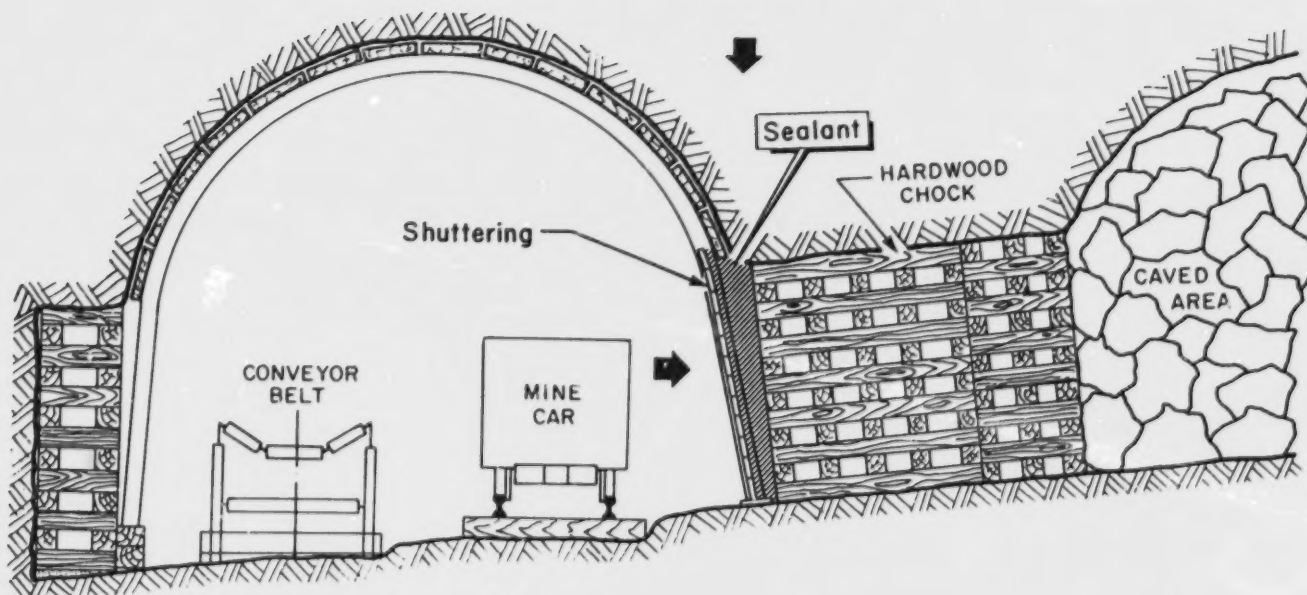


SIDE VIEW

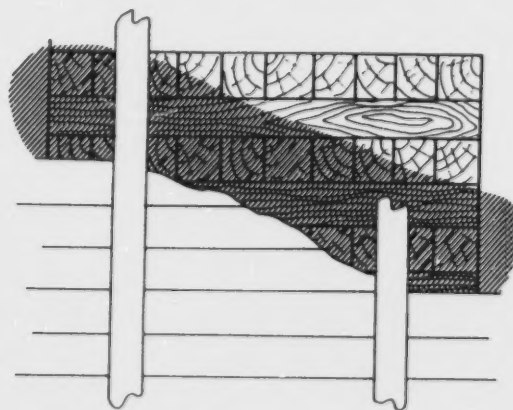
AR-73

FIGURE 2-2
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

SHUTTER AND FILL



TOP VIEW

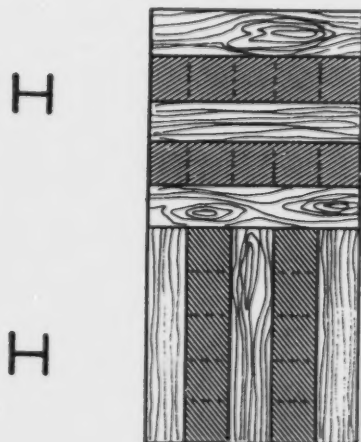
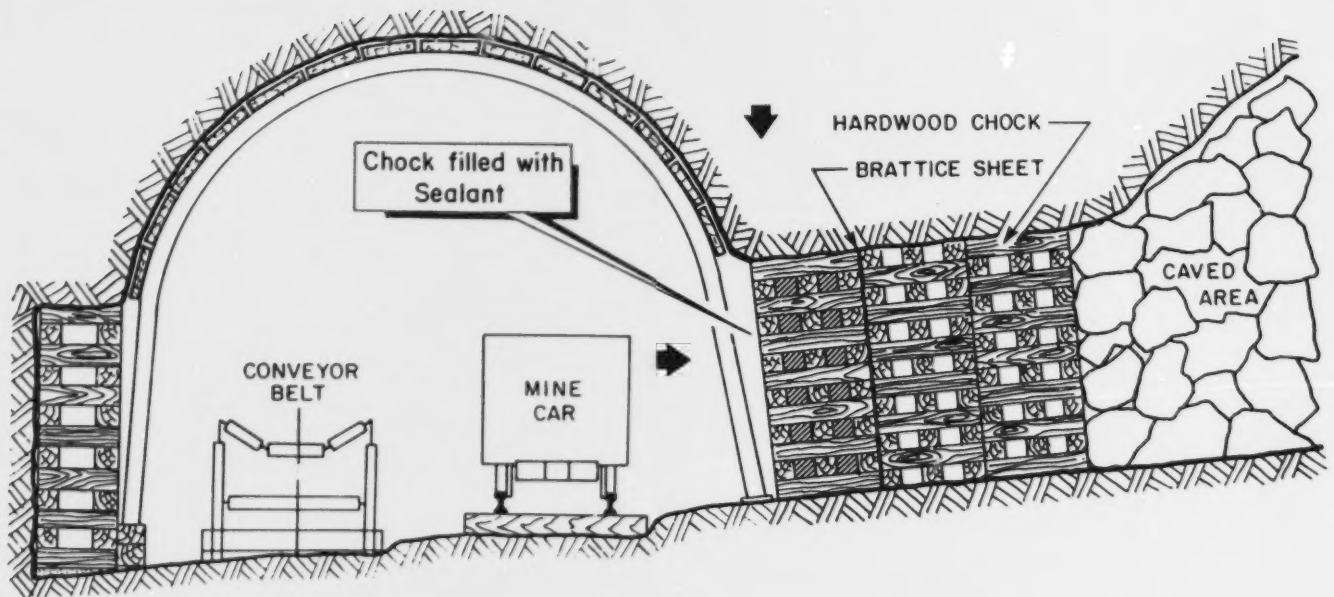


SIDE VIEW

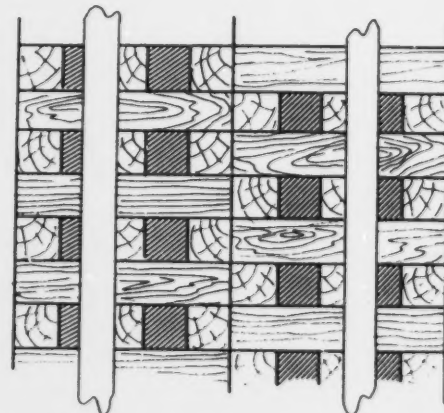
AR-73

FIGURE 2-3
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

SEALANT BLOCK



TOP VIEW

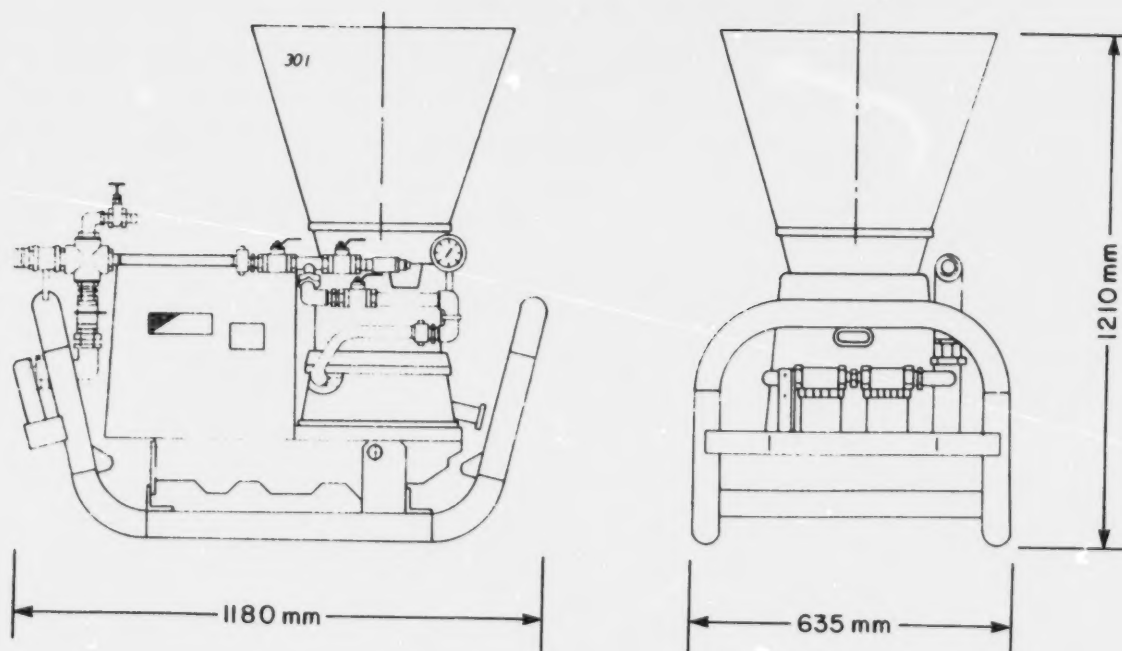


SIDE VIEW

AR-73

FIGURE 2-4
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

ALIVA DRY PROCESS MACHINE



AR-73

FIGURE 2-5
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

ALLENTOWN GUNITE MACHINE

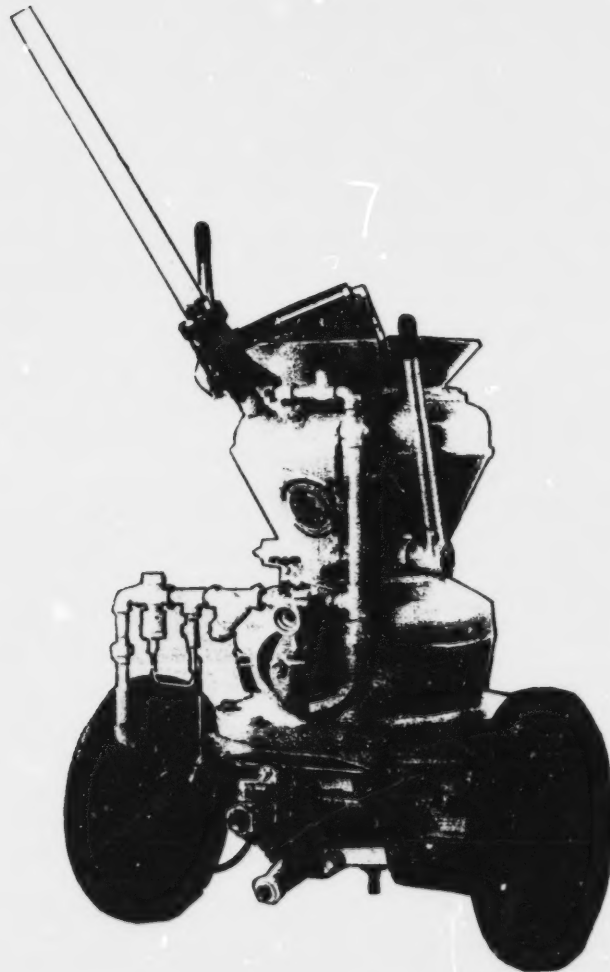
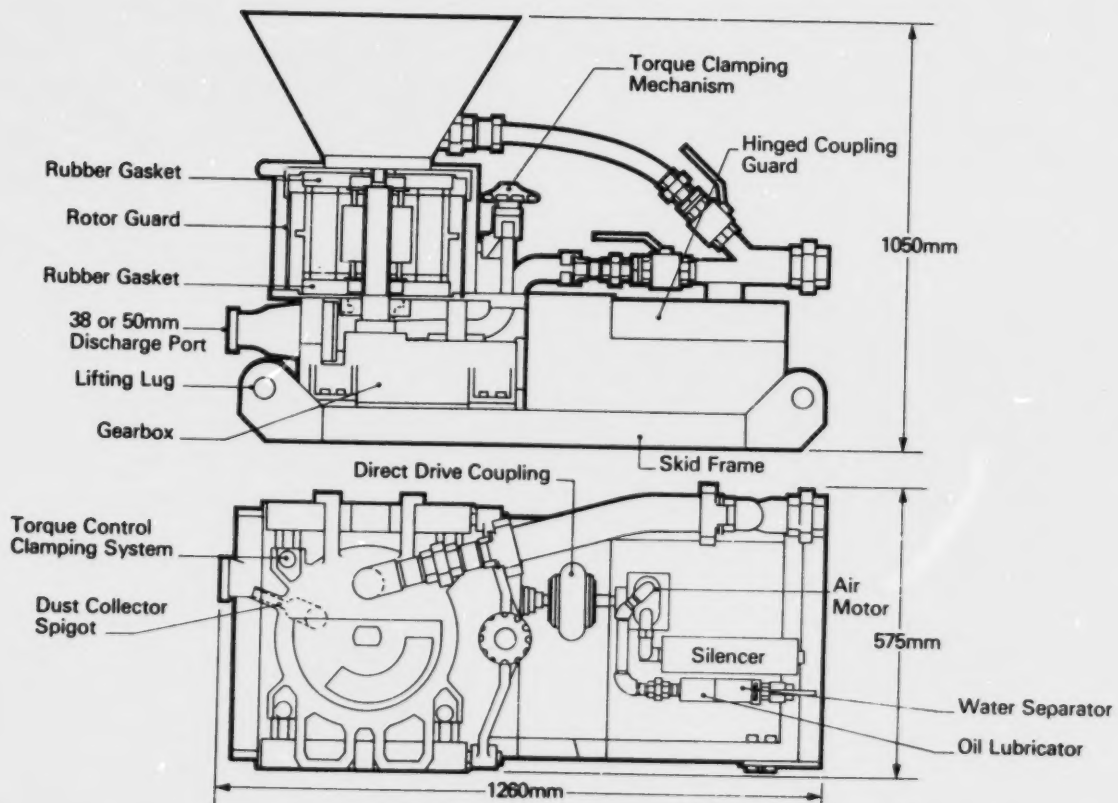


FIGURE 2-6
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

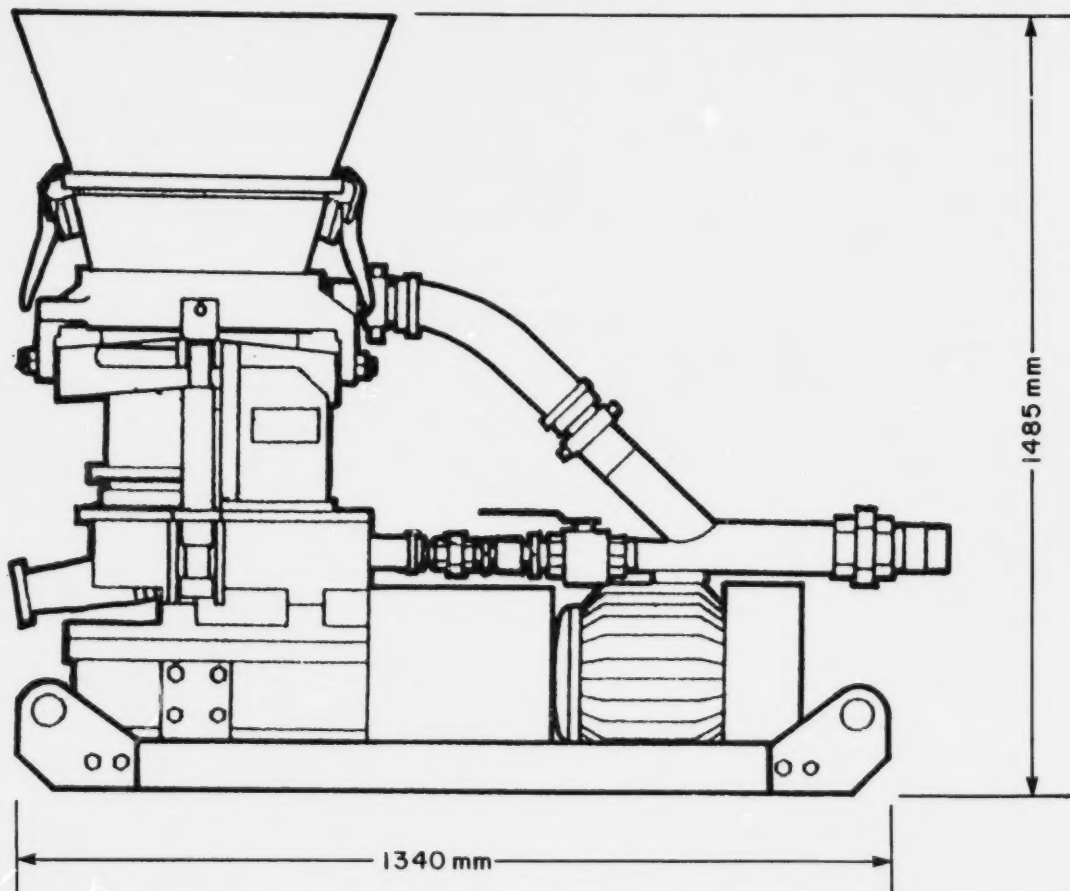
MARKHAM HIGH PRESSURE DRY PROCESS MACHINE



AR-73

FIGURE 2-7
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

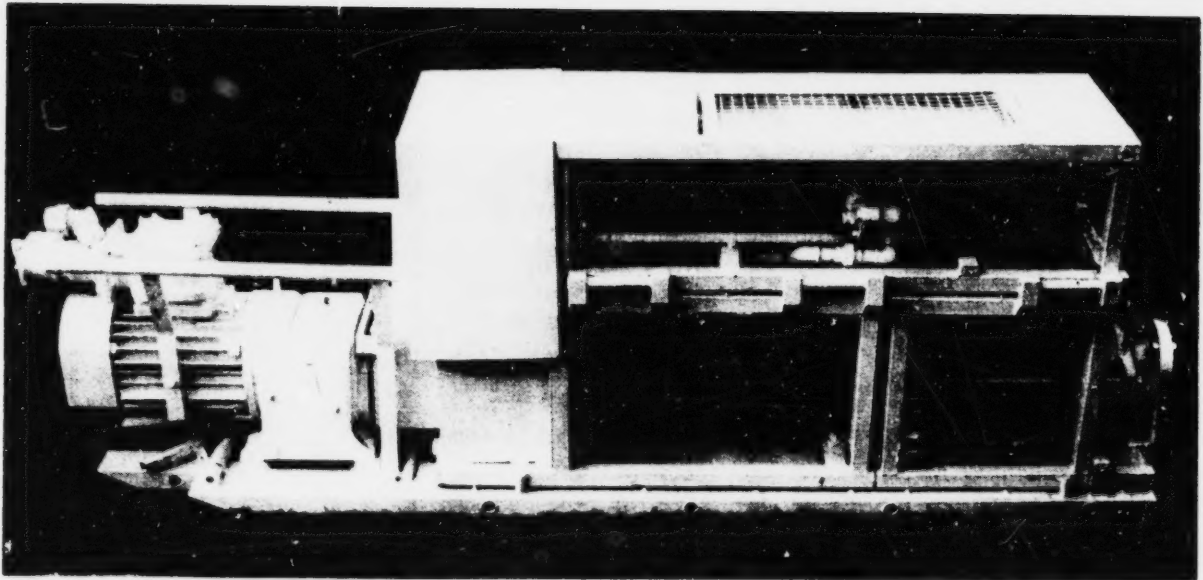
MARKHAM LOW PRESSURE DRY PROCESS MACHINE



AR-73

FIGURE 2-8
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

VARIMIX WET PROCESS MACHINE



AR-73

FIGURE 2-9
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 73SQ.23440-3-9033

STRONG SEALMASTER WET PROCESS MACHINE

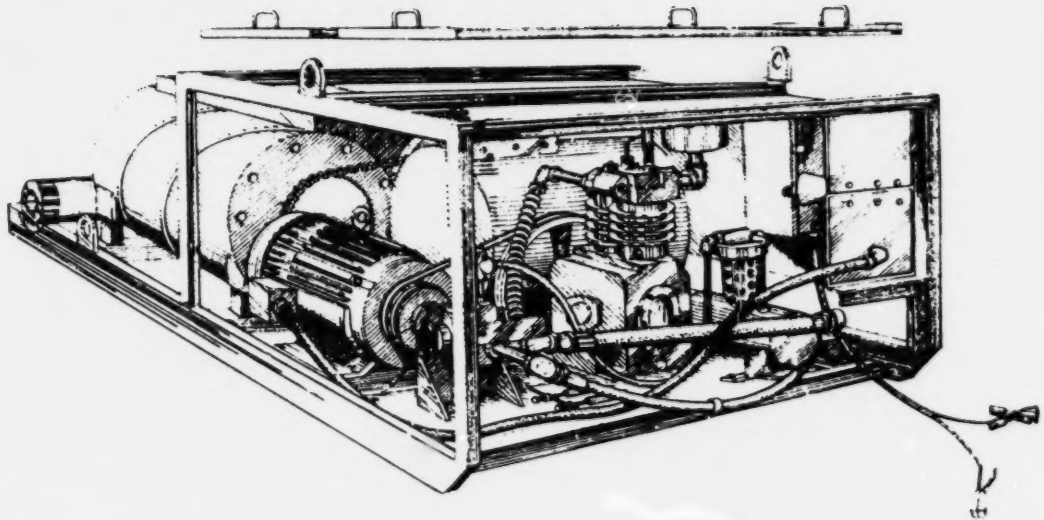
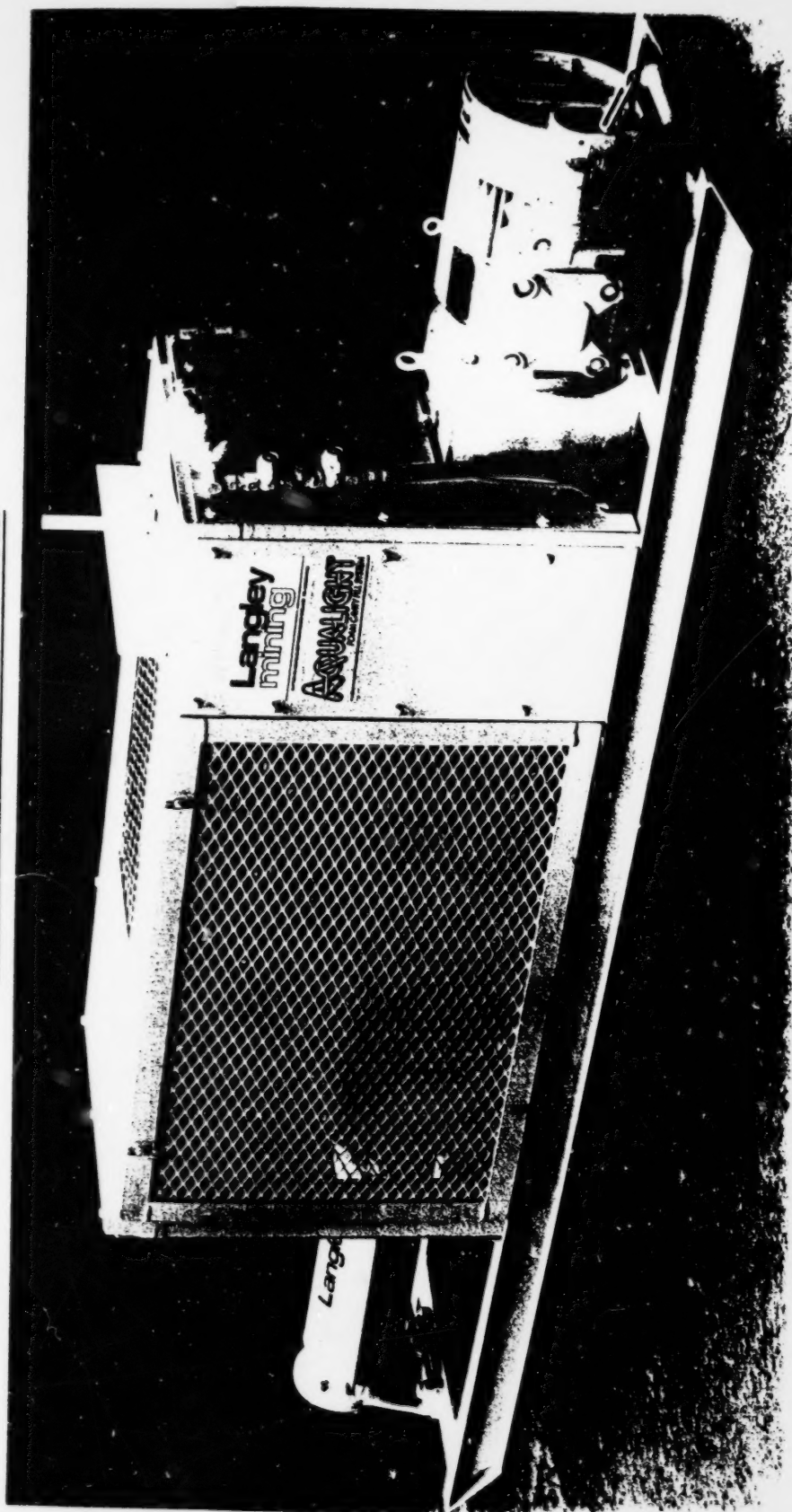


FIGURE 2-10
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

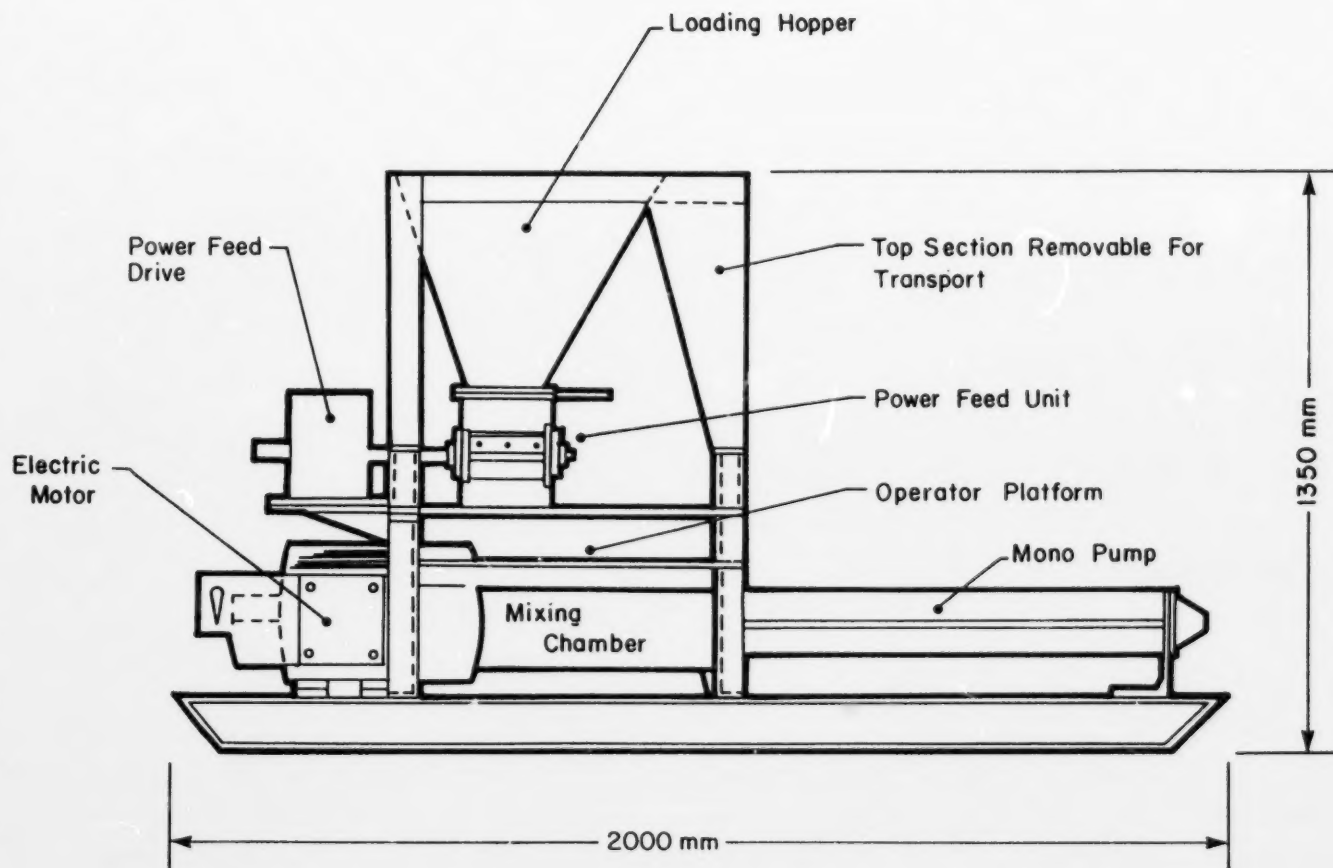
LANGLEY FOAMED CEMENT PLACER



AR-73

FIGURE 2-11
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

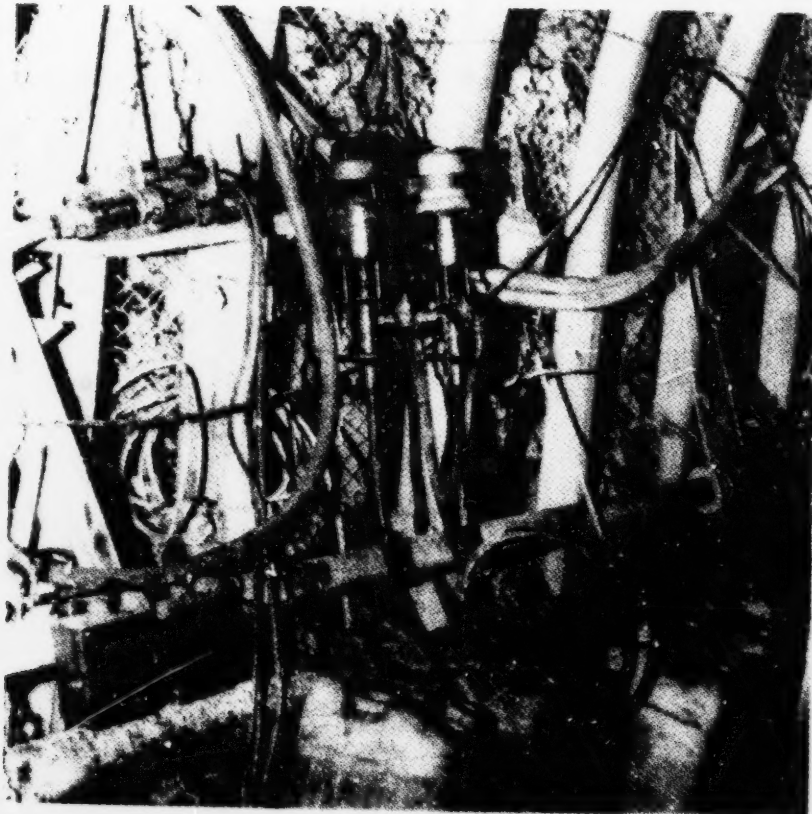
COLCRETE FOAMED CEMENT PLACER



AR-73

FIGURE 2-12
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

UREA FORMALDEHYDE FOAM PLACER



A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
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SECTION 3 - SUITABILITY

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3.4.3 Procedure	3-3
3.5 Alternative Methods	3-5

TABLES
(Following Text)

- 3-1 Material Requirements (Aqualight)**

FIGURES
(Following Tables)

- 3-1 Langley Foamed Cement Placing Machine**
- 3.2 Colcrete Foamed Cement Placing Machine**
- 3-3 Schematic Layout of Sealant Operation**

SECTION 3 - SUITABILITY

3.1 INTRODUCTION

In this section the criteria for sealant selection are defined. Following the review of sealants described in Section 2 the most appropriate method, equipment and material for sealing on advancing walls in the Sydney Coalfield are identified. In addition, alternative sealant techniques are discussed.

3.2 SUITABILITY CRITERIA

The best method of sealing is to build a monolithic pack. Then, ranked in descending order of effectiveness, sealant block, shutter and fill and coating with sealant. Monolithic packing is outside the scope of this study and the sealing method recommended is the construction of a sealant block.

For the construction of a sealant block the sealant material should have the following characteristics:

- non-flammable, non-toxic and safe to handle
- low permeability to air flow
- mechanical properties adequate to sustain its effectiveness within the pack
- ability to fill a chock or alleyway without additional shuttering
- capable of being bulked-up on site
- minimum manpower for materials transportation and placing of the sealant
- the sealing operation should not interfere with production
- approved or capable of being approved for use in underground coal mines by an established regulatory authority
- acceptable to the workforce
- in use elsewhere in applications similar to those in the Sydney Coalfield

- easy to store and handle
- cost should be as low as possible.

3.3 RECOMMENDED SEALANT

For the recommended method of sealing by sealant block the candidate sealants identified meeting the criteria listed above are urea formaldehyde foam, phenolic foam, foamed cement and foamed gypsum. However, urea formaldehyde foam is not acceptable for use in CBDC mines and will not be further considered.

The alternative sealants, therefore, are phenolic foam, foamed cement or foamed gypsum. Foamed cement appears to be the best alternative since it is an inorganic material and is lower cost than phenolic resin foam and its expansion ratio is better than foamed gypsum. Trials should be conducted with foamed cement so that its effectiveness can be fully assessed. Equipment, materials and procedures are described in 3.4 below.

3.4 RECOMMENDED EQUIPMENT, MATERIALS AND PROCEDURES

3.4.1 Equipment

A Langley or Colcrete placing machine (see Section 2.3) should be obtained for mixing and pumping the foam. These machines are approved by the NCB for use in underground coal mines and are the only units suitable for placing Aqualight.

The machine is assembled on a skid base (Figures 3-1 and 3-2) and it is recommended that it be mounted on the stage loader or on a suitable structure riding on the belt conveyor so that it is advanced regularly with the wall and does not obstruct access for materials.

The machine should have an electric supply of appropriate voltage and requires a minimum water delivery of 90 L/min. No compressed air is necessary. It is essential that the delivery line from the machine comprises at least 20 m of 20 mm armoured hose.

The estimated cost of such a placing unit, delivered to Sydney, Nova Scotia, is approximately \$11,000 - \$15,000.

3.4.2 Materials

The sealant material is known by the trade name of Aqualight and is manufactured by Pozament Cement Limited. The standard size pack is 25 kg, supplied in 5-ply paper bags with polythene liners. The product is approved for use in NCB mines under Acceptance number A2418. (Though this approval was granted for use in cavity filling, acceptance by the NCB confirms that the material is considered safe for use in underground coal mines).

3.4.3 Procedure

Although the foam can bridge quite large gaps or cavities, steps taken to contain the foam will minimize usage and increase its effectiveness. Where the roadhead system incorporates an alleyway, it is recommended that one side at least should be walled solid with chock wood and the other covered with brattice before placing the foam. Where there is no alleyway and the chock immediately adjacent to the roadside is filled, the back of the chock should butt against a solid wall of chock wood or should be lined with brattice.

An adequate supply of Aqualight should be available at the pump (Table 3-1). It is estimated that approximately 3 to 4 25 kg bags of Aqualight will be required per metre of 0.76 m x 0.76 m

roadside chock to be filled, or 6 to 7 25 kg bags per metre of alleyway.

Before commencing foam delivery the area to be filled should be cleared of loose debris and materials and the floor should be cleaned up. Loose strata should be dressed down. Any large holes in the chocks or alleyway should be plugged up or, if necessary, covered with brattice.

After site preparation is completed sealant placing can be undertaken. The maximum distance between the pump and the point of discharge can be up to 120 m.

The pump can be operated at high or low speed by selecting the appropriate gear shift position. In the high setting the machine processes one 25 kg bag per minute and delivers approximately 15 m³ of foam per hour. In the lower speed setting the delivery rate is approximately half. It is estimated that a two-man crew can prepare for, and place sufficient sealant in one shift to cover one week's face advance.

Basic precautions should be taken when handling Aqualight as with all cement based materials. PVC gloves, dust masks and goggles should be used. Barrier creams provide additional protection.

The sealing should be regularly checked for leakage and, where necessary, defective damaged areas should be repaired. A denser block can be produced by adjusting the water delivery rate, or selecting a different delivery hose length or diameter.

3.5 ALTERNATIVE METHODS

Should operational considerations preclude the use of the sealant block method with foamed cement, then alternative methods should be considered. The alternatives in descending order of suitability are:

- Aerostem in place of Aqualight
- shuttering between the flanges of the arches and backfilling with Aqualight, Aerostem or conventional cement or gypsum based sealants
- surface coating of suitably prepared solid chock wall or pack side with cement or gypsum based sealant.

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TABLE 3-1
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

MATERIAL REQUIREMENTS (AQUALIGHT)

Wall Advance (m)	Fill Roadside Chock		Fill Alleyway	
	(25 kg bags)	(kg)	(25 kg bags)	(kg)
5	15-20	375- 500	30- 40	750-1000
10	30-40	750-1000	60- 80	1500-2000
15	45-60	1125-1500	90-120	2250-3000

FIGURE 3-1
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS

DSS No. 23SQ.23440-3-9033

LANGLEY FOAMED CEMENT PLACING MACHINE



FIGURE 3-2
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

COLCRETE FOAMED CEMENT PLACING MACHINE

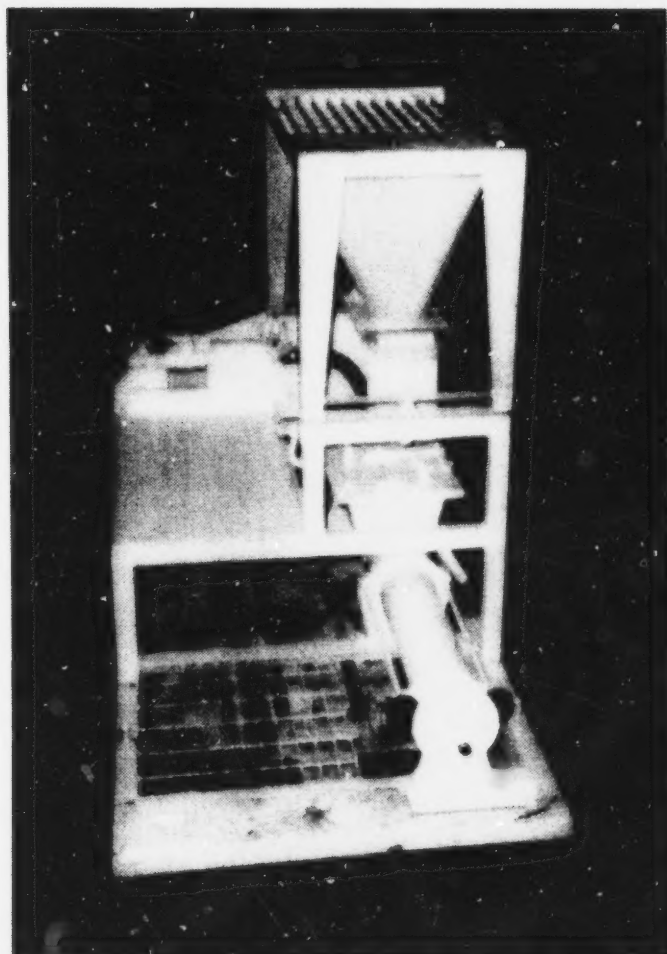
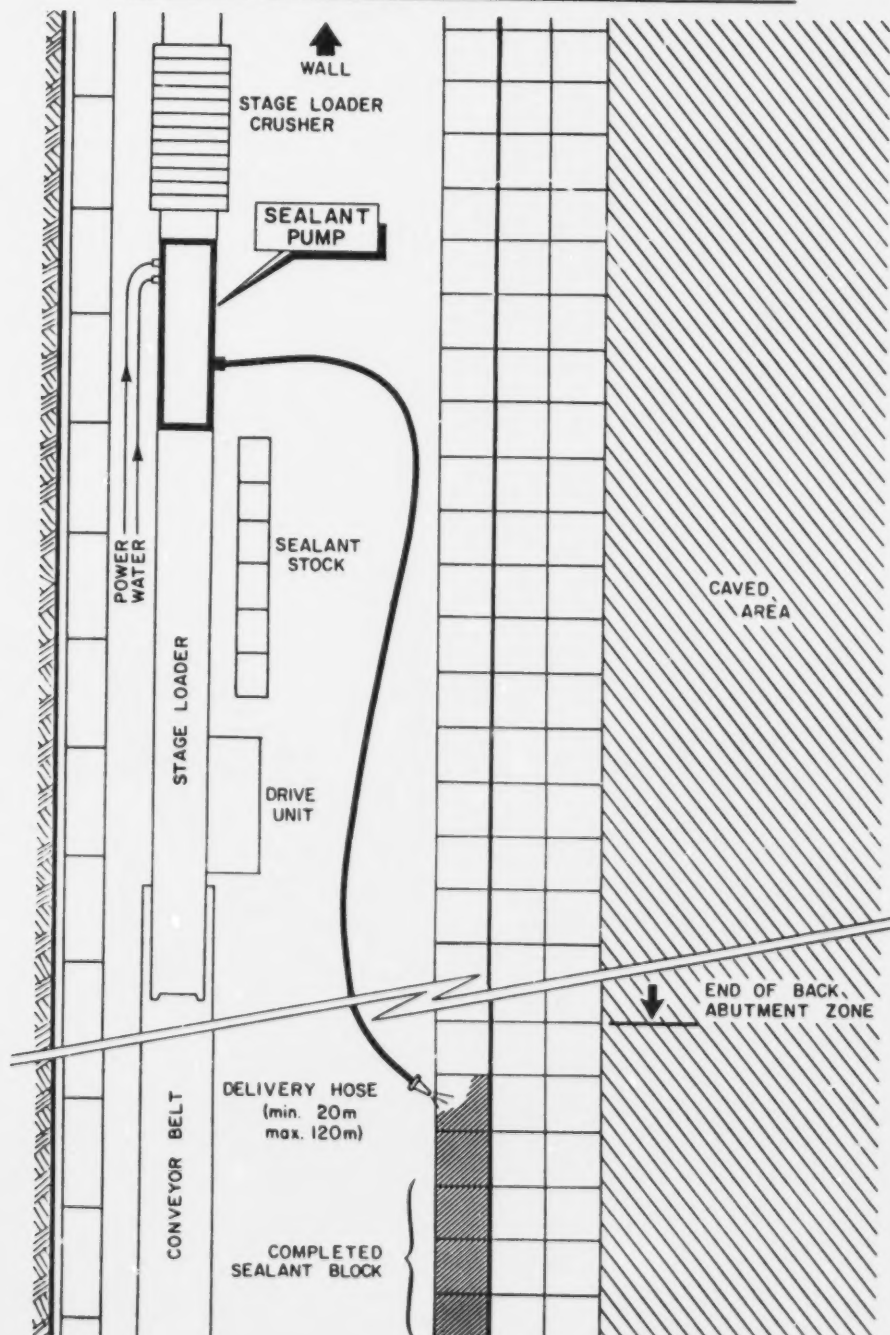


FIGURE 3-3
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033

SCHEMATIC LAYOUT OF SEALANT OPERATION



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A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
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SECTION 4 - SEALANT TESTING PROTOCOL

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.....Cont'd

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A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
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SECTION 4 - TEST PROTOCOL

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FIGURES
(Following Text)

- 4-1 Laboratory Air Permeability Test
- 4-2 Permeability Test Rig

SECTION 4 - TESTING SEALANT PROTOCOL

4.1 INTRODUCTION

During the development of a new sealant a range of laboratory tests are frequently conducted. The testing procedure for any developed sealant can be split into two separate categories:

- safety testing
- performance testing

The basic requirements for a developed sealant are that it meets approved standards for use in underground coal mines and that it effectively minimises air leakage across the gob of advancing longwall faces. Secondary criteria are that the sealant should be capable of being readily applied by permissible equipment with proven reliability, that it is cost-effective, requires minimum manpower and that the process of application does not interfere with the mining operation. Having limited the number of sealants, the test protocol can be followed.

After safety clearance has been obtained, underground trials in the actual operating conditions will give the most meaningful results.

4.2 SAFETY TESTING

The following tests should be made prior to any sealant being approved for use underground:

4.2.1 Non-Combustibility Tests

The material should be non-combustible when tested in accordance with BS476:Part 4:1970 - "Non-combustibility test for materials", or ASTM E136-81 - "Behaviour of materials in a vertical tube furnace at 750°C". The tests are similar in concept.

This test requirement has the effect of confining sealant coatings to non-combustible inorganic materials. Around 3% organic matter by weight is normally sufficient to make a material combustible.

4.2.2 Spread of Flame Test

The material should comply with a Category 1 spread of flame when tested in accordance with BS 476-Part 7:1971, or have a flame spread index of less than 5 when tested in accordance with ASTM E84-81a. - 'Surface burning characteristics of building materials'.

4.2.3 Toxicity Test

The material should be non-toxic at normal and elevated temperatures and during mixing, pumping, application and setting. The test procedures should be developed based on the chemical analysis of material to be tested, since this will give a guide to the likely products of combustion. A toxologist should design the appropriate test work, review the results and provide a professional report on the toxicity of the material.

Products of combustion can be sampled for analysis during testing in accordance with ASTM E84-81a.

4.2.4 Fire Gallery Test

Materials which are used in large quantities or in potentially hazardous locations may require more thorough investigation before they can be accepted for use underground. Laboratory testing can sometimes be misleading in that combustion characteristics and products of combustion can be quite different in a full-scale situation. Thus, for new materials, which are not totally inorganic, a full-scale fire gallery test is advisable.

A typical fire gallery consists of a tunnel 110 m long constructed from 3.6 m x 2.7 m steel arches spaced at 0.9 m intervals along a concrete pad. The spaces between the arches being fitted with reinforced concrete blocks. The inside is sprayed with a vermiculite-based cement to insulate and protect the structure and the outside is treated with a resin-bonded cement to render it waterproof. A forcing fan is sited at one end of the gallery.

Within the gallery is a 27 m long test zone starting 16 m downwind of the fan. In this zone the floor, roof and sides are provided with additional insulation and there is a set of 2.4 m x 2.1 m arch rings spaced at 0.9 m intervals to provide a framework for experimental materials.

The severity of the fire conditions can be altered. Typical igniting sources can be 500 kg of wood, part of which consists of cribs of half-rounds of timber mounted above the floor of the gallery and part of which is untreated coverboards lining the bays in the gallery adjacent to the cribs. The air speed is set at about 2 m/s corresponding to a volume flow of 20 m³/s.

Facilities are provided for recording temperatures throughout the length of the gallery, for continuous gas analysis and closed circuit televising with video record.

An extract from a report on a fire gallery test on Aqualight is given as Appendix C.

4.2.5 Health Hazards

The material should present no short or long-term health hazard during handling, mixing, application or setting. It is difficult to define a universal test program for this parameter and an assessment should be made based on the composition of the material. For example, asbestos should not be included in the product.

The pH value of the material will give an indication of likely skin irritation, although concentration of acids or alkalis is of equal importance. The odour given off by the material can only be realistically assessed by the human nose.

4.2.6 Static Electricity

The material should not give rise to sparkings due to static electricity during handling, mixing or application. A suitable test is method AI March 1976 of Charbonnage de France.

4.2.7 Discussion

The above tests define whether the sealant materials is safe for use underground. They do not define the properties required to prevent air leakage across the gob of an advancing longwall face.

4.3 PERFORMANCE TESTING

4.3.1 Underground Trials

Having identified potential sealant materials in a preliminary review and conducted the necessary testwork to obtain approval for use underground, the most practical method of assessing the material is by an underground trial. The efficiency of new sealants should be established in relationship to those currently in use.

A 100 m length of the intake gateroad of a working panel should be designated as a test section. The sealant should be applied in accordance with the manufacturer's specified procedure and under their supervision. The method of application would depend on the type of sealant to be tested.

4.3.2 Evaluation During Application

During application a number of parameters would be measured or observed:

- rate of application per metre advance
- reliability of mixing/pumping system
- labour requirements
- equipment cleaning requirements
- adhesion properties to wood, rock, coal, steel and broken or dusty surfaces
- set time
- bridging effect in cavities
- rebound losses
- liability to cracking during and after drying
- liability to spalling
- colour and its effect on visibility in the gateroad
- evaluation of cost of application per metre advance taking into account labour, material and equipment costs.

4.3.3 Evaluation of In Place Performance

Once the test section is completed further tests should be carried out:

- **Air Loss:** This could be measured by measuring air flow rates at each end of the test section and calculating the losses by difference. The air losses would have to be related to the air pressure differential across the sealant and brought to a common basis for comparison purposes.

Air leakage increases with pressure differential according to the formula:

$$Q = aP^n,$$

where:

- Q = air leakage per unit of sealant area
- P = pressure differential
- a = air leakage at unit pressure differential
- n = an exponent, normally between 0.5 and 1, dependent on air flow pattern

(Source: USBM Report of Investigation 6710).

The air loss test would be repeated at intervals of 3 months to establish the effect of time and strata movement on the behaviour of the sealant.

- **Smoke Test:** A smoke source can be introduced at points along the test section. Observation of the smoke flow pattern will identify the location of any leakage points along the sealed pack.
- **Cracking or Spalling:** Liability to cracking or spalling over time as convergence or strata occurs must be observed and recorded.
- **Repair Costs:** Any costs of repair work should be established.
- The ability to withstand impact during mining operation should be evaluated.

The above tests would establish a comparison in terms of effectiveness at preventing air leakage and costs on a long-term basis in the operating conditions of the mine, and would represent the best assessment of the sealant material.

4.4 LABORATORY TESTING PROCEDURE

In developing a new sealant for mining use, laboratory tests are useful to establish specific indications of certain properties. These tests should be considered as preliminary to underground trials.

A laboratory approach to testing potential sealant materials would be to carry out a suite of tests which would give an indication of the important characteristics of a sealant.

A matrix could be developed with each property weighted according to its importance. Failure to meet minimum criteria in certain properties would eliminate the material from further consideration.

The following testing procedures could be included:

4.4.1 Air Permeability

Air permeability measurements could be undertaken using methods adapted from those used by the USBM for block stoppings as recorded in their Report of Investigations 6710.

Laboratory Scale

Figure 4-1 shows schematically the test apparatus required. The sealant material, placed on a porous backing sheet to a predetermined thickness, forms one wall of a sealed chamber. Compressed air is forced into the chamber. The measured rate of air input

required to maintain a given pressure differential across the sealant gives the rate of air leakage through the sealant.

Use of a soap solution outside coating will visually indicate the air leakage paths.

Large Scale

More meaningful data could be obtained if a larger scale test facility were built on the surface, so that the full pack complete with sealant could be tested. A schematic diagram of such a facility is shown in Figure 4-2. A detailed design would be required.

The test rig is similar in principle to the laboratory scale testing apparatus. A non-permeable container is built with one open side. The simulated pack coated with the sealant is built to cover this open side. Compressed air is pumped into the container and the air flow measured to maintain the desired pressure differential across the test panel. A port in the container wall and video camera would allow visual observation of the sealant surface.

Facilities would be incorporated in the design to apply a load to the test pack, by use of an hydraulic press (similar to one available at CANMET's Elliot Lake Laboratory) or a loading frame complete with hydraulic jacks. In this manner the convergence of roof or floor can be simulated and the effect of the deformation on the sealant measured.

4.4.2 Compressive Strength

This parameter should be tested in accordance with ASTM C 109-80 'Standard Method of Test for Compressive Strength for Hydraulic Cement Mortars'.

4.4.3 Flexural Strength

Tested in accordance with ASTM E 72-80 'Conducting Strength Tests for Panels for Building Construction'.

4.4.4 Thermal Conductivity

Tested in accordance with ASTM C 177-76 'Steady-state Thermal Transmission Properties by Means of the Guarded Hot Plate'.

4.4.5 Storage Conditions

The resistance to freezing and thawing cycles can be tested in accordance with ASTM C 666 'Resistance of Surface Bonding Mortar to Freezing and Thawing'.

4.4.6 Bulk Density

A one m³ container is filled with material in its applied condition. The bulk density is calculated from the weight of material in the container.

4.4.7 Flow Characteristics

The flow characteristics may be important both for pumping the material and to prevent slumping on application. Viscosity should be measured during mixing and in applied form.

4.4.8 Water Solubility

A test should be devised to measure the ease of clean-up of mixing and pumping equipment at set times after use.

4.4.9 pH Value and Acid/Alkali Concentrations

The pH and acid/alkali concentrations will give an indication of potential hazards of skin contact during handling.

4.4.10 Colour

Visual observation of the colour of set sealant should be made. Clearly a light colour is most desirable on exposed surfaces underground.

4.4.11 Adherence

The important property of adhesion to mine surfaces cannot normally be predicted, and can only be proven in in-mine trials.

FIGURE 4-1
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
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LABORATORY AIR PERMEABILITY TEST

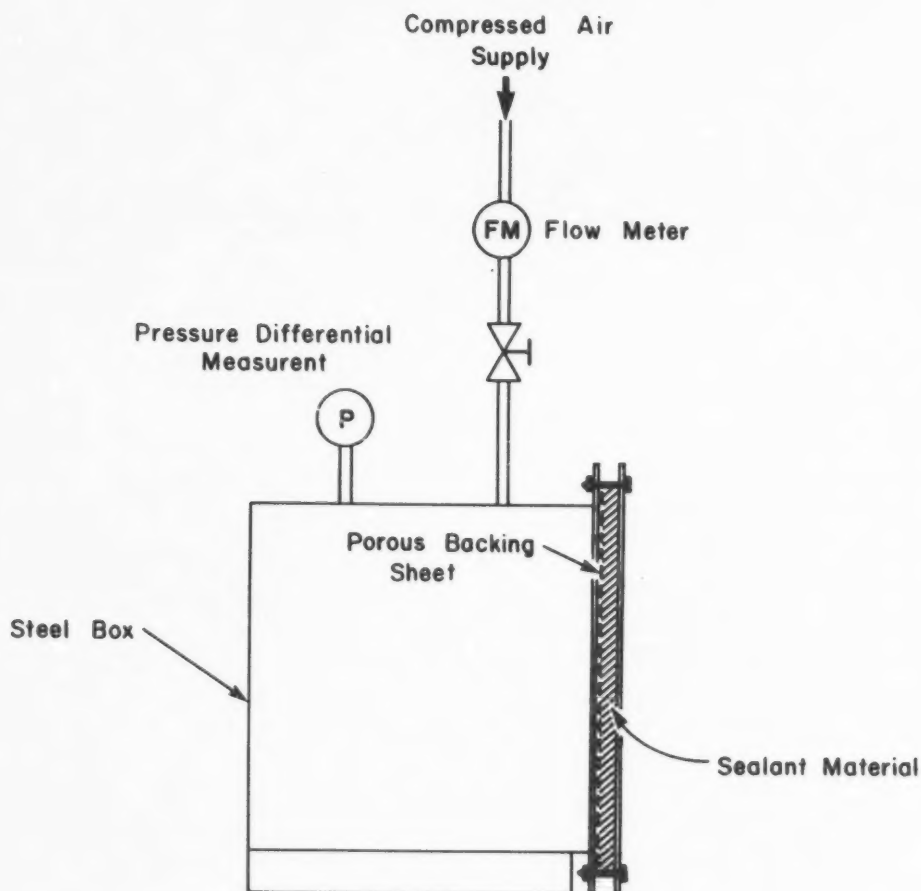
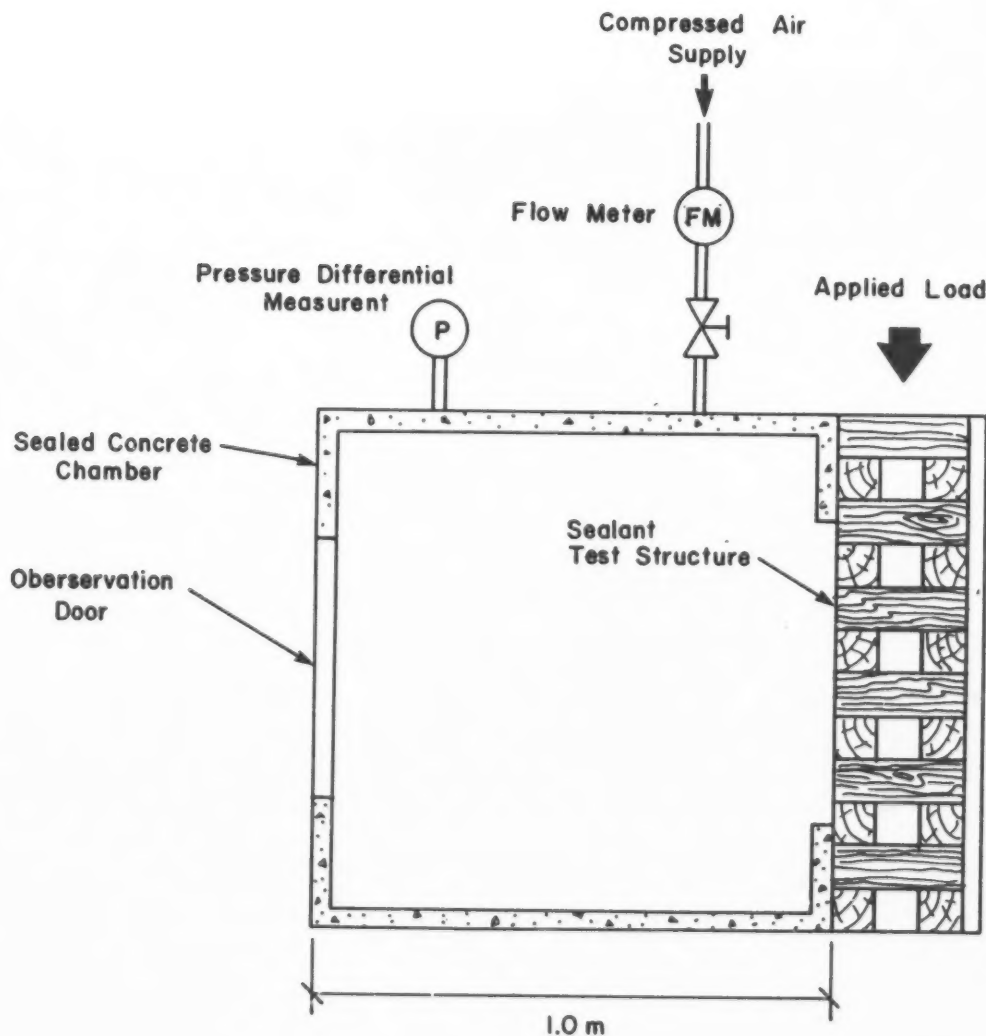


FIGURE 4-2
A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
DSS No. 23SQ.23440-3-9033
PERMEABILITY TEST RIG



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A DETAILED REVIEW OF GATEROAD SEALANTS
TO REDUCE GOB LEAKAGE IN
ADVANCING LONGWALL SECTIONS IN THE SYDNEY COALFIELDS
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SECTION 5 - RESEARCH AND DEVELOPMENT

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SECTION 5 - RESEARCH AND DEVELOPMENT

5-1 INTRODUCTION

Much research and development work related to sealants has been carried out by most of the major coal industries of the world. This work has been in two principal areas - the safety of sealants and their effectiveness in the mining situation. Areas where Canadian research and development might be focussed are suggested below.

5.2 CANADIAN RESEARCH AND DEVELOPMENT

Research and development activities that could benefit the Canadian coal industry include:

- Surface testing of new sealant materials to appraise their safety and to make an assessment of their performance potential.
- In-mine trials to assess the performance of sealants not previously applied in Canada, including Aqualight, Aerostem and other materials.
- In-mine trials to compare quantitatively the leakage reduction obtained by surface coating, shutter and fill, sealant block and monolithic packing.
- A comprehensive study of air flow around a longwall district to include methane emission patterns and rates, gob air flows, leakage patterns and methane drainage efficiency. This would be a broad based approach to determine the most cost effective way of achieving improved ventilation conditions.
- Regular review of international developments in the field of mine sealant methods and materials. For example, CMI in Poland are currently working on the development of a new epoxy based sealant. This and other developments should be monitored.

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5-2

These research and development suggestions should be reviewed jointly by CANMET and mine operators and a priority listing developed.

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APPENDIX A

List of Manufacturers Contacted

MANUFACTURERS CONTACTED

ACME Chemical Co.	Inca Co., The
Aliva Ltd. (Switzerland)	James River Limestone Co. Inc.
Allentown Pneumatic Gun	J.P. Austin Associates Inc.
Alchem Inc.*	Langley Mining Ltd.
American Energy Group	M & T Chemicals*
American Energy Products	Malaysian Rubber R&D Board
Ashland Chemicals*	Mandoval Ltd.
Atlas Copco (Canada) Ltd.	Markham and Co. Ltd.
A. Weber SA	Mine Safety Appliances Co.
Babcock & Wilcox Refractories*	Nalco Chemical Company
B-Bond Industries Inc.	Ostler Rocky Mountain Refractories
BFC Packed Products	Polar Chemical*
British Gypsum	Q-Bond Corporation of America
Burrell Construction & Supply	Pozament Cement
Castable Compositions	Pyro Chem, Inc.
Celtite Incorporated	Qwikrete Companies
Chemical Building Products	Stone Mountain Mfg. Co. Inc.
Chemical Building Product Holdings	Stormont Chemicals Ltd.*
Coal Industry Services Co.	Strataseal Incorporated
Coal Industry Service Company (CISCO)	Thermocoat Incorporated
Conproco, Avilite Industries	Therm-O-Rock Incorporated
Degussa Canada*	Thickol Canada*
Dohm London Ltd.	Reed Manufacturing Erie
Eimco Mining Machinery International	Strong-Lite Products Co.
Eimco Process Machinery	US Gypsum
Erco Industries*	US Steel
Faswall Incorporated	United States Mineral Products Co.
Flintkote of Canada (now Bakelite)	Unifoam Company*
Harris Mining Company	Wallace Construction Specialties Ltd.
Harrison & Crossfield (Canada)*	Western Chemical Co.
Henkel Chemicals (Canada)*	Wolf-Pruf Inc.
Genstar Stone Products Co.	Woodruff Supply Co. Inc.
	W.R. Bonsal Company
	W.R. Grace & Co.

* Non-mining Sealants

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APPENDIX B

Sealing Material Data Sheets
(Price stated in Canadian dollars)

Trade Name: Aerostem

Manufacturer: British Gypsum Ltd.
Ruddington Hall
Loughborough Road, Notts, U.K.
Tel: 0602 844 844

Composition: Gypsum foamed with Aluminum Sulphate and Sodium Bicarbonate

Intended Use: Cavity filler

Limitations: Not suitable for prolonged exposure to temperatures greater than 125°C

Method of Delivery: Premixed in bags

Shelf Life: 3 - 12 months depending on storage conditions

Mixing Procedure: Mechanical. 50 kg Aerostem to 30 L water

Application Method: Wet or dry spray
Expansion 2.2:1

Thickness: Dependent on application

Setting Time: 10 - 15 Minutes

Elasticity: Tends to crush under load rather than crack. Impact absorbed by local indentation

Adherence: Good adherence to most surfaces, but tends to be applied to contained areas

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic

Stability: Stable over long periods

Approving Authority: NCB (UK)

Trade Name:	Gypseal
Manufacturer:	British Gypsum Ltd. Ruddington Hall Loughborough Road, Notts, U.K. Tel: 0602 844844
Composition:	Exfoliated vermiculite and gypsum. Organics 0.2% - 0.3%.
Intended Use:	Sealant for leakage prevention.
Limitations:	Not suitable for prolonged exposure to temperatures greater than 125°C.
Method of Delivery:	Pre-mixed in bags.
Shelf Life:	3 - 12 months.
Mixing Procedure:	Mechanical. 50 kg Gypseal to 36 l water.
Application Method:	Wet slurry spray. Sometimes gunhead wetting or hand application.
Thickness:	25 mm as sealant 5 - 10 mm as fire retardant
Setting Time:	90 minutes.
Elasticity:	Internal reinforcement of either wire mesh or fibres required in conditions liable to appreciable strata movement.
Adherence:	Adherence to most backgrounds includes coal, pack sides, sandbags, steel, brickwork and mesh. Hardwood may need mesh support. Dusty surfaces should be wetted. Application over running or seeping water difficult.
Fire Retardant Properties:	Non-combustible Few cracks under fire conditions No smoke or vapour.

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Data Sheet 2

B-3

Toxicity: Non-Toxic.

Stability Stable over long periods.

**Approving
Authority:** NCB (UK)

Trade Name: Hardstem.

Manufacturer: British Gypsum Ltd.
Ruddington Hall,
Loughborough Road
RUDDINGTON, Notts. U.K.
Tel: 0602 844 844

Composition: Gypsum and additives
No organics.

Intended Use: Sealant for leakage prevention
Fire retardent.

Limitations: Not suitable for prolonged exposure to temperatures greater than 125°C.

Method of Delivery: Premixed in bags.

Shelf Life: 3 - 12 months dependent on storage conditions.

Mixing Procedure: Mechanical or hand mixing
50 kg Hardstem to 24 l water

Application Method: Pump or wet slurry spray.
Shuttering normally required.

Thickness: Dependent on site conditions.
Not normally less than 100 mm - 150 mm.

Setting Time: 15 minutes

Elasticity: Cracks under strata load.
Impact absorbed by local indentation.

Adherence: Satisfactory adhesion to most surfaces can only be obtained if applied as thin layer (2.5 mm). Thicker coatings tend to flake off easily.

Fire Retardent Properties: Non-combustible.

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Data Sheet #3

B-5

Toxicity: Non-toxic

Stability Stable over long periods

**Approving
Authority:** NCB (UK)

Trade Name:	Hardstop
Manufacturer:	British Gypsum Ltd. Ruddington Hail Loughborough Road Ruddington, Notts. U.K. Tel: 0602 844 844
Composition:	Gypsum plus additives Organics 0.09% Shortset, 0.19% Longset
Intended Use:	Sealant coating for leakage prevention
Limitations:	Not suitable for prolonged exposure to temperatures greater than 125°C.
Method of Delivery:	Premixed in bags
Shelf Life:	3 - 12 months dependent on storage conditions
Mixing Procedure:	Mechanical or hand mixing 50 kg Hardstop to 24 l water
Application Method:	Pump or spraying machine Normally behind shuttering
Thickness:	Dependent on site conditions Normally greater than 100 mm - 150 mm
Setting Time:	30 minutes - short set 90 minutes - long set.
Elasticity:	Tendency to crack under strata load. Minor impact absorbed by local indentation.
Adherence:	Satisfactory adherence to most surfaces only if applied as very thin coating (2.5 mm). Thicker coatings tend to flake off easily
Fire Retardant Properties:	Non-combustible

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Data Sheet #4

B-7

Toxicity: Non-toxic

Stability Stable over long periods

**Approving
Authority** NCB (UK)

Trade Name:	Rubberised Gypsum Plaster
Manufacturer:	Pusat Penyelidikan Getch Malaysia 260 Jalan Ampang Kuala Lumpur 16-03 Malaysia Tel: 467-033 or MPRRA (Malaysian Rubber Producers Research Association) Brickendonbury Hertford, Herts. U.K.
Composition:	Gypsum plaster and latex rubber
Intended Use:	Air sealant
Limitations:	Requires support. Designed for sealing block stoppings
Method of Delivery:	Gypsum base premixed in bags. Latex in drums
Shelf Life:	2 - 6 months depending on storage conditions
Mixing Procedure:	Mix gypsum base with latex to get desired rubber content
Application Method:	Hand trowel or slurry spray
Thickness:	2 mm
Setting Time:	4 - 8 hours
Elasticity:	Improved elasticity over gypsum type sealants. Resists cracking under load
Adherence:	Adheres well to metal, wood, mine strata, etc.
Fire Retardent Properties:	Flame retarded. Will not support combustion
Toxicity:	Non-toxic

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Data Sheet 5

B-9

Stability

Stable over long periods

**Approving
Authority:**

Used in South African mines

Trade Name:	Aqualight
Manufacturer:	Pozament Cement Limited Queen Street Woodlesford LEEDS, Yorkshire, LS26 8AL U.K. Tel: 0532-867121
Composition:	Blend of non-toxic cementitious materials with additives and foaming agent which forms foam cement
Intended Use:	Lightweight cementitious fill for pumping into cavities, stoppings and backfilling roadway arches
Limitations:	Special placing machine required
Method of Delivery:	Premixed in bags
Shelf Life:	3 months
Mixing Procedure:	Mechanical in Langley machine. 50 kg Aqualight to 50 kg water Expansion ratio up to 15:1
Application Method:	Pump into cavity with limited formwork
Thickness:	Dependent on application
Setting Time:	5 minutes approximately
Elasticity:	Yields under load due to porous nature. Does not crack
Adherence:	Adheres to most underground conditions, but foam normally constrained with formwork or liner until set
Fire Retardent Properties:	Non-combustible
Toxicity:	Non-toxic. Normal precautions required as in handling Portland cement
Stability	Stable over long periods
Approving Authority:	NCB (UK)

Trade Name: BB-GUN-ite

Manufacturer: BBond Industries
PO Box 271
Latrobe
PA 15650
Tel: (412) 539-6600

Composition: AR(alkali resistant) fiberglass reinforced gunite

Intended Use: Gunite or shotcrete

Limitations: Thickness of application minimum 12.5 mm. Dry spray only

Method of Delivery: Premixed in 22.6 kg bags

Shelf Life: 3 - 6 months, depending on storage conditions

Mixing Procedure: No mixing required

Application Method: Dry spray application

Thickness: Minimum 12.5 mm

Setting Time: 2 - 3 hours at normal temperatures

Elasticity: Brittle

Adherence: Good, wire meshing sometimes required

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic.
Normal precautions when handling Portland cement

Stability Stable over long periods

Approving Authority: MSHA (US)

Trade Name: BLAZE GUARD

Manufacturer: American Energy Products Corporation
667 Brea Canyon Road
Suite 20-B
Walnut
CA 91789
Tel: (714) 594-0015

Composition: Magnesium oxysulphate based insulating cement, containing lightweight fillers

Intended Use: Fire protective coating for organic foams

Limitations: Not as fast setting or as strong as magnesia cement

Method of Delivery: Premixed in kg bags

Shelf Life: 6 months in dry conditions

Mixing Procedure: Mechanical. 50 kg Blaze-Guard to 40 L water

Application Method: Trowel application or wet or dry spraying

Thickness: 6 mm - 25 mm

Setting Time: 2 - 4 hours initial set

Elasticity: None

Adherence Good adherence to most underground surfaces. Helps bond cracked or loose surfaces:

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic

Stability Stable over long periods

Approving Authority: MSHA (US)

Trade Name:	Bucshot and Bucshot 222 (Coarse)
Manufacturer:	Pozament Cement Ltd. Queen Street Woodlesford LEEDS, Yorks. LS26 8AL U.K. Tel: 0532 867121
Composition:	Sand, cement with accelerator Organics negligible
Intended Use:	Sealant coating
Limitations:	Cracks under load
Method of Delivery:	Premixed in bags.
Shelf Life:	2 - 4 months depending on storage conditions
Mixing Procedure:	Dry process spraying - mixed in spray nozzle. Too dry a mix reduces adhesion and gives dust. Too wet a mix impairs end-product strength, permeability and adhesion
Application Method:	Sprayed in dry process spray equipment
Thickness:	5 mm - 25 mm
Setting Time:	15 - 20 minutes
Elasticity:	Brittle, cracks under load
Adherence:	Good to most mining surfaces
Fire Retardent Properties:	Non-combustible
Toxicity:	Non-toxic. Normal precautions when handling Portland cement
Stability	Stable over long periods
Approving Authority:	NCB (UK)

Trade Name: FIBERCOAT II

Manufacturer: Austin Industrial Coatings Corp.
300 Mt. Lebanon Boulevard
Pittsburgh
PA 15234
Tel: (412) 563-3300

Composition: Portland cement with glass fibers

Intended Use: Coating for stoppings to increase strength and reduce air leakage

Limitations: Cracks under load
Primarily designed as coating for block stoppings

Method of Delivery: Premixed in 22.6 kg bags

Shelf Life: 2 - 3 months depending on storage conditions

Mixing Procedure: Manual or mechanical

Application Method: Hand trowel or wet spray

Thickness: 3 mm

Setting Time: Initial set 2 hours

Elasticity: Liable to crack under load

Adherence: Adheres well to block walls. Not suitable for application to dusty or oily surfaces

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic
Normal precautions for Portland cement required

Stability Stable over long periods

Approving Authority: MSHA (US)

Trade Name: FLYASH-CEMENT

Manufacturer: Ingredients purchased separately

Composition: Flyash, cement

Intended Use: Stoppings

Limitations: High volume of material handling

Method of Delivery: Cement in bags. Flyash in bulk

Shelf Life: 3 - 6 months depending on storage conditions

Mixing Procedure: Hand or mechanical
62% flyash
7% Portland Cement
31% water

Application Method: Hand or pump spray

Thickness: Dependent on use

Setting Time: Initial set 2 - 4 hours

Elasticity: Good. Plasticity allows flow under load

Adherence: Excellent bond to mine strata that are wet, dirty and loose

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic. Normal precautions for Portland cement

Stability: Stable over long periods

Approving Authority: N/A

Trade Name: GENSTAR Mine Sealant Mix

Manufacturer: GENSTAR Stone Products Company
Executive Plaza IV
Hunt Valley
MD 21031
Tel: (301) 628-4000

Composition: Portland cement, glass fibres, silica sand

Intended Use: Air sealant on block walls in underground mines

Limitations: Used as sealant on block walls

Method of Delivery: Premixed in bags

Shelf Life: 3 - 12 months, depending on storage conditions

Mixing Procedure: Manual - 50 kg mix to 30 L water

Application Method: Brushed

Thickness: 3 mm - 12.5 mm

Setting Time: 28 days to full set

Elasticity: Brittle

Adherence: Designed for adherence to concrete blocks. Loose material must be removed or bonded prior to application of sealant

Fire Retardant Properties: Non-combustible

Toxicity: Non-toxic. Normal precaution for Portland cement

Stability: Stable over long periods

Approving Authority: MSHA (US)

Trade Name: Inca Mine Sealants (INCA 1500)

Manufacturer: The Inca Co
Stanton and Empire Streets
Wilkes Barre
PA 18702
Tel: (717) 822-2191

Composition: Cement/fiber glass or poly-fibres/other additives

Intended Use: Sealing roof and rib, building block stoppings

Limitations: Cracks under load

Method of Delivery: Premixed in 22.7 kg bags

Shelf Life: 1 year if stored unopened in dry place

Mixing Procedure: Manual or mechanical

Application Method: Trowel/spray (wet or dry)

Thickness: 3 mm minimum to 50 mm in multiple applications

Setting Time: Initial set 2 hours - final 28 days

Elasticity: Brittle - very hard

Adherence: Excellent

Fire Retardent Properties: Zero flame spread (same as concrete)

Toxicity: None

Stability: Very stable - same as Portland cement

Approving Authority: MSHAS (US)

Trade Name: Mandoseal

Manufacturer: Mandoval Ltd.
Mark House, The Square
LIGHTWATER, Surry, U.K.
Tel: 0276 71617

North American Agent:
Austin Industrial Coatings Corp.
300 Mt. Lebanon Boulevard
PITTSBURGH, PA 15255, USA.

Composition: Delaminated exfoliated vermiculite, Portland cement,
whiting and additives.
Less than 0.3% organics.

Intended Use: Sealant coating for leakage protection

Limitations: Cannot be used below 0°C.
Alkaline in wet mix form.

Method of Delivery: Premixed in bags.

Shelf Life: 6 - 12 months in cool dry conditions.

Mixing Procedure: Mechanical or hand.
50 kg Mandoseal to 36 l water.

Application Method: Wet slurry spray.
Sometimes gunhead wetting or hand application.

Thickness: 25 mm as sealant
5 mm - 10 mm as fire retardant.

Setting Time: More than 2 hours.

Elasticity: High degree of compressibility.
Impact absorbed by local indentation.

Adherence: Adheres to most backgrounds including coal, pack sides,
sandbags, steel supports, brickwork and mesh.
Hardwood may need mesh support.
Dusty surfaces should be wetted.
Application over running or seeping water difficult.

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Data Sheet 14

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**Fire Retardent
Properties:**

Non-combustible
No smoke or vapour under fire conditions.
Only slight damage by fire.

Toxicity:

Non-toxic
only precautions in use are as per Portland cement.

Stability

Stable over long periods.

**Approving
Authority:**

NCB (UK) / MSHA (US)

Trade Name: MINE GUARD

Manufacturer: American Energy Products Corp.
667 Brae Canyon Road
Suite 20-B
Walnut
CA 91789
Tel: (714) 594-0015

Composition: Magnesia based inorganic cement. % organics - zero

Intended Use: Protection of mine tunnel strata from air slacking

Limitations: Non-elastic, cracks under load. Wood requires priming

Method of Delivery: Premixed in bags

Shelf Life: 6 months if stored in dry conditions

Mixing Procedure: Mechanical. 50 kg Mine Shield to 15 L water

Application Method: Slurry spray or dry spray

Thickness: 12.5 mm - 50 mm
Maximum one coat application 300 mm

Setting Time: 1.5 - 2 hours initial set

Elasticity: None. Wire mesh required for reinforcement

Adherence: Adheres well to rock, coal, metal. Wood needs to be previously sealed with latex based adhesive/sealant

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic. Normal precautionary measures required when handling cement products

Stability Stable over long periods

Approving Authority: MSHA (US)

Trade Name: MINE-SHIELD

Manufacturer: United States Mineral Products Co.
Stanhope
NJ 07874
Tel: (201) 347-1200

Agent:
Cem-Al Products Ltd.
20 Laidlaw Boulevard
Markham, Ontario
L3P 1W7
Tel: (416) 294-9240

Composition: Proprietary cementitious binders and mineral glass fibres

Intended Use: Coating mine strata and building air stops

Limitations: Cracks under load
Designed for coating block stoppings

**Method of
Delivery:** Premixed in bags

Shelf Life: Up to 1 year, depending on storage conditions

**Mixing
Procedure:** Dry spray

**Application
Method:** Dry spray

Thickness: 3 mm minimum, 12.5 mm normal

Setting Time: Initial set 2 hours approximately

Elasticity: Brittle

Adherence: Adheres to most mining backgrounds

**Fire Retardent
Properties:** Non-combustible

Toxicity: Non-toxic

Stability: Stable over long periods

**Approving
Authority:** MSHA (US)

Trade Name: Strataseal MS-1

Manufacturer: Strataseal Inc.
163 Orchard Drive
McMurray
PA 15317
Tel: (412) 941-6444

Composition: Aggregate and cement, plus additives

Intended Use: Sealants and stoppings, fireproofing, protective coatings, insulation, water barrier controls, sound control, architectural

Limitations: Needs backing material

Method of Delivery: Premixed in bags

Shelf Life: 3 - 6 months depending on storage conditions

Mixing Procedure: Nozzle mixing, mechanical or manual
50 kg Strataseal to 40 L water

Application Method: Wet slurry spray or manual.
Mesh used to support unstable areas.

Thickness: Minimum 12.5 mm

Setting Time: Firm 1 - 2 hours. 28 days to full strength

Elasticity: Compressible without cracking

Adherence: Excellent to wood, urethane, shale, coal and cement block backgrounds

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic
Normal precautions using Portland cement

Stability: Stable over long period

Approving Authority: MSHA (US)

Trade Name: Strong-Seal MS1

Manufacturer: Strong Systems Inc.
PO Box 8029
Pine Bluff
AR 71611
Tel: (502) 536-3453

Composition: Portland Cement and expanded perlite plus additives less than 0.1% organics

Intended Use: Air loss control and protect against spalling

Limitations: Spalls and cracks under load

Method of Delivery: Premixed in bags

Shelf Life: 6 months depending on storage conditions

Mixing Procedure: Hand or mechanical

Application Method: Wet spray

Thickness: 12.5 mm

Setting Time: 4 hours

Elasticity: Low

Adherence: Good to most underground conditions

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic. Normal precautions for Portland cement

Stability: Stable over long periods

Approving Authority: MSHA (US)

Trade Name: Strong-Seal MS-2

Manufacturer: Strong Systems Inc.
PO Box 8029
Pine Bluff
AR 71611
Tel: (501) 536-3453

Composition: Portland cement, expanded perlite and fiberglass filler plus additives
less than 0.01% organics

Intended Use: Coating for stoppings

Limitations: Spalls under load; designed for coating block stoppings

Method of Delivery: Premixed in bags

Shelf Life: 6 months depending on conditions

Mixing Procedure: Hand or mechanical

Application Method: Trowel

Thickness: 3 mm

Setting Time: Up to 2 hours

Elasticity: Low

Adherence: Good to all underground materials

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic. Normal precautions during handling for Portland cement

Stability: Stable over long periods

Approving Authority: MSHA (US)

Trade Name: Supaspray

Manufacturer: BFC Packed Products Ltd.
Griff Lane
Griff Clara
NUNEATON, Warwickshire
CV1D 7PP U.K.
Tel: 0682 347924/5

Composition: Sand and cement
Negligible organics

Intended Use: Gunite/spray concrete mix

Limitations: Cracks under load

Method of Delivery: Premixed in bags.

Shelf Life: Greater than 3 months

Mixing Procedure: Mechanical
50 kg supaspray to 22 l water

Application Method: Spray/Gunite Machine

Thickness: As required

Setting Time: 2 hours approximately

Elasticity: Brittle, cracks under load

Adherence: Good to most mining surfaces

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic
Normal precautions in handling Portland cement

Stability: Stable over long periods

Approving Authority: NCB (UK)

Trade Name: Superspray with Additive

Manufacturer: BFC Packed Products Ltd.
Griff Lane
Griff Clara
NUNEATON, Warwickshire
CV1D 7PP U.K.
Tel: 0682 347924/5

Composition: Sand, cement with Tricosal TI low caustic accelerating powder
Negligible organics

Intended Use: Gunite/Spray concrete Mix

Limitations: Cracks under load

Method of Delivery: Premixed in bags.

Shelf Life: Greater than 3 months depending on storage conditions

Mixing Procedure: Mechanical
50 kg supaspray to 22 l water

Application Method: Spray/Gunite Machine

Thickness: As required

Setting Time: 15 - 20 minutes

Elasticity: Brittle, cracks under load

Adherence: Good to most mining surfaces

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic
Normal precautions in handling Portland cement

Stability Stable over long periods

Approving Authority: NCB (UK)

Trade Name: Tite Bond

Manufacturer: Strataseal Inc.
163 Orchard Drive
McMurray
PA15317
Tel: (412) 941-6444

Composition: Cement and glass fibre mixture

Intended Use: Airlock, air stoppings, underground wall construction

Limitations: Designed mainly as coating for block stoppings. Spalls off under load

Method of Delivery: Premixed in bags

Shelf Life: 3 - 6 months depending on storage conditions

Mixing Procedure: Spray/Manual. 50 kg Tite-Bond to 21 L water

Application Method: Spray or trowel

Thickness: 3.2 mm minimum

Setting Time: Initial set 4 hours, final set 5.75 hours

Elasticity: Good flexural strength

Adherence: Mainly designed for block walls. Blocks should be free of any foreign material if good bond is to be obtained

Fire Retardent Properties: Non-combustible
Normal precautions while using Portland cement

Toxicity: Non-toxic

Stability: Stable over long periods

Approving Authority: MSHA (US)

Trade Name: Airstop

Manufacturer: Chemical Building Product Holdings Ltd.
Vimy Road
LEIGHTON BUZZARD, Beds., LU7 7ER, U.K.
Tel: 0525 375646

Composition: Blend of inorganic paste and filler.
Organics 0%.

Intended Use: Fire resistant sealant.

Limitations: Designed for coating stoppings

Method of Delivery: Premixed in 25 kg steel drums

Shelf Life: Greater than 6 months.

Mixing Procedure: Premixed.

Application Method: Hand trowel or spray.

Thickness: 3 mm - 6 mm

Setting Time:

Elasticity:

Adherence:

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic

Stability: Stable over long periods

Approving Authority: NCB (UK)

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Trade Name: C.C. Sealant

Manufacturer: Castable Compositions Ltd.
2 School Green
Bramhope
LEEDS, Yorks, LS16 9By, U.K.
Tel: Leeds 674586

Composition: Calcined shales and low bulk density refractory insulating materials. 0% organics

Intended Use: Fireproof coating to prevent air leakages.

Limitations:

Method of Delivery: Premixed in 25 kg polythene bags.

Shelf Life: 6 months.

Mixing Procedure: Mechanical mixer or in spraying equipment
50 kg C.C. Sealant to 24 l water.

Application Method: Pneumatic spraying or manual.

Thickness: Maximum 25 mm.

Setting Time:

Elasticity:

Adherence:

Fire Retardent Properties: Non-combustible

Toxicity: Non-toxic

Stability: Stable over long periods

Approving Authority: NCB (UK)

Trade Name: IGLONEIGE FJ 253

Manufacturer: A. Weber
F-57520 Rouhling
France
Tel: (8) 709-1097

Composition: Modified urea formaldehyde resin foam

Intended Use: Stoppings, roadway sealant to reduce air leakage

Limitations: Suspected long-term health problems related to urea formaldehyde prohibit use in Canada Melts at 120°C.

Method of Delivery: Resin and catalyst separately in 30 kg cans

Shelf Life: 3 - 5 months

Mixing Procedure: Special foam mixing equipment. 2 volume resin to 1 volume catalyst

Application Method: Pumped through pipeline to constrained area

Thickness: Dependent on application

Setting Time: Coagulates in 30 s
Polymerizes in 2 h
Final set in 4 days

Elasticity: Crushes under load but does not crack

Adherence: Poor adhesion to rock. Applied to constrained area

Fire Retardent Properties: Non-combustible

Toxicity: Produces urea formaldehyde and hydrogen cyanate gas when heated.
Precautions required to avoid skin contact during handling

Stability Stable over long periods

Approving Authority: Charbonnages de France (France)

Trade Name: MARIFLEX GE

Manufacturer: A. Weber S.A.
F-57520 Rouhling
France
Tel: (8) 709-1097

Agent:
ECO Geochemical Consulting Ltd.
301, 336 - 5 Avenue North
Saskatoon, Saskatchewan
S7K 2P4
Tel: (306) 242-3323

Composition: Two component, expanding phenoplast type resin

Intended Use: Cavity fill, fire stopping, roadway sealant

Limitations: Low mechanical strength. Special equipment required

Method of Delivery: Resin and catalyst delivered separately in cans

Shelf Life: 3 - 5 months

Mixing Procedure: Special mixing, foaming, pumping set
4 volumes resin to 1 volume catalyst

Application Method: Pumped into space confined with cloth or wire mesh/polyethylene sheet.
Expands 35:1

Thickness: Dependent on application

Setting Time: Immediate reaction, final set in 5 minutes

Elasticity: Will crush with weight but does not crack

Adherence: Excellent to coal and rock strata

Fire Retardant Properties: Non-combustible

Toxicity: Inert when set. During setting a small amount of urea formaldehyde gas is formed

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Stability

Stable over long periods. Can be drilled

**Approving
Authority:**

Charbonnages de France (France)

Trade Name: Mariflex 'P'

Manufacturer: A. Weber
F - 57520 Rouhling
France
Tel: (8) 709.10.97

Composition: Three component resin

Intended Use: For spray applications, fireproofing

Limitations: Gives off urea formaldehyde during installation
Still in research state, not available commercially

Method of Delivery: In drums and bags

Shelf Life: Winter - 5 months
Summer - 3 months

Mixing Procedure: Mix and spray

Application Method: Spray

Thickness: 25 mm

Setting Time: Sets on contact

Elasticity: Will crush with weight but will not crack

Adherence: Excellent, with rock and coal

Fire Retardent Properties: Classified as non-flammable in Europe. Probably classed as fire retardant in Canada

Toxicity: Urea formaldehyde fumes given off during spraying.
Operator must be protected and good ventilation provided.

Stability Stable indefinitely

Approving Authority: Charbonnage de France (France)

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APPENDIX C

**Extract from
Fire Gallery Performance Trials on Aqualight
by H.A. Hines
April 1983**

1. INTRODUCTION

Aqualight is an aerated cement material developed at MRDE for use as an underground cavity filling. It is manufactured by Pozament Cement Ltd. and is supplied as a dry powder. When mixed with water and air and sprayed under pressure into a cavity it sets to form a lightweight, air impregnated cement grout. The curing time is approximately one or two days at normal underground temperatures.

Following a request to the NCB Non Metallic Materials Committee by Dr. Johnson of MRDE, Aqualight was subjected to a large-scale fire test in the Yorkshire Regional Laboratory (YRL) Fire Gallery on 17:03:03. The purpose of the test was to establish the behaviour of Aqualight under normal conditions of intended use with respect to mechanical deformation and heat damage as a result of a major fire. A total fire load of 450 kg dried timber was burned in a linear ventilation flow of 2 m/s.

2. TEST CONFIGURATION AND PROCEDURE

A 6 m length of the simulated roadway section, commencing at bay 5 through to bay 10, was lined on the outside of the rings with treated cover boards. The inside of the arches was then lined with 5 cm square weldmesh, over which polythene sheeting was secured and a second layer of weldmesh was secured in the roof to give additional support. The cavity between the rings, approximately 15 cm deep, was then filled with Aqualight, by removing several cover boards in the roof. The Aqualight was then left to cure with air heaters being used to maintain a temperature approximating to a return roadway. The sections of weldmesh in the roof and the polythene sheeting were removed and the fire test conducted one week later.

The roadway lining configuration of this test, although not simulating a 'typical' practical usage, does represent a 'worst case' application by

exposing maximum surface area per unit volume to the effects of flame and hot gases from the fire.

The wood loading consisted of 150 kg cover boards placed between the rings and bays 3 and 4 directly adjacent to the Aqualight, and two 150 kg pine wood splits cribs placed adjacent to bay 3, making a total loading of 450 kg. Both the pine wood splits and the cover boards were dried to below 10% moisture content prior to the test. The cribs were ignited simultaneously by means of paraffin soaked wood wool.

Temperature measurement throughout the test was made using six thermocouples secured to the weldmesh in the Aqualight lining or hung on chains from the roof of the gallery. The thermocouple positions were at distances of 2.5 m and 5 m from the cribs respectively. The temperatures were recorded on the URL data logger at one minute intervals.

The linear ventilation speed down the gallery was set at 2 m/s before the test.

Gaseous products of combustion were continuously drawn from a sampling point 80 m down the gallery to the control room where they were analysed for CO and CO₂ by infra-red absorption and paramagnetically for O₂.

The test was monitored and recorded on a closed circuit video system.

3. RESULTS AND DISCUSSION OF EVENTS

Temperatures were recorded at 2.5 m and 5 m from the fire. The curves and their peaks are typical of past results obtained from crib based gallery fires as are the gas analysis data which peaked during the same period at 4.5% CO₂, 1400 ppm CO and 4.5% O₂ deficiency.

A second peak in temperatures occurred some 15 minutes into the test, and was also evident in the gas analysis. At this point most of the cover boarding from the roof had fallen to the floor, giving a more intense ground fire for a period.

After approximately 20 minutes the Aqualight lining could be seen clearly through the collapsing crib. No visual evidence of combustion could be seen.

4. OBSERVATIONS AFTER THE TEST

4.1 Treated Cover Boards

The treated cover boards in the roof were well burned on the upper exposed surface along the entire length of the test section. In the roof of bay 7 the boards were still burning with a visible flame one hour after the test. In bays 9 and 10 the Aqualight lining of the roof had several gaps in it where the Aqualight had not adhered on filling or had fallen out before the test. In these positions the cover boards had burned on the underside also. The front edges of the side wall boards in bay 5 had burned and the damage spread down the gallery with increased height.

The burning of the treated boards was probably due to a long period of outside storage with the treatment being partially washed out due to weathering. A considerable amount of protection was afforded to the boards by the Aqualight with no evidence of burning on the Aqualight lined surface of any boards.

4.2 Aqualight

No major structural damage to the Aqualight or any evidence of combustion was observed after the test. Slight surface discolouration was observed, especially in the sides of bay 5. Cracks of minimal depth were observed at several points on the surface, giving a 'dried salt flat' appearance, probably caused by rapid heating and subsequent cooling. The areas around the leading edge of bay 5 where the Aqualight appears to have been partially damaged were caused by the boarding up of bay 4 and not as a result of the fire.

5. CONCLUSIONS

Having been subjected to flame impingement, radiant heat flux and the effect of hot gases from a major fire, under conditions which approximate to a worst case example of intended use, Aqualight showed no evidence of combustion and no major structural damage.

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APPENDIX D

Sealant Materials - Quick Reference

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D-1

MATERIALS FOR SURFACE COATING

Name	Date Sheet #
GYPSUM	
Aerostem	#1
Gypseal	#2
Hardstem	#3
Hardstop	#4
Rubberized Gypsum Plaster	#5
CEMENT	
BB-GUN-ite	#7
Blazeguard	#8
Bucshot	#9
Fibrecoat II	#10
Genstar Mine Sealant Mix	#12
INCA 1500	#13
Mandoseal	#14
Mine Guard	#15
Mine Shield	#16
Strataseal MS1	#17
Strong-Seal MS1	#18
Strong-seal MS2	#19
Superspray	#20
Superspray with additive	#21
Tite-Bond	#22
OTHER	
Airstop	#23
C.C. Sealant	#24
Mariflex 'P'	#26

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D-2

MATERIALS FOR SHUTTER AND FILL

Name

Date Sheet #

GYPSUM

Aerostem
Hardstem
Hardstop

#1
#3
#4

CEMENT

Aqualight
Flyash Cement

#6
#11

OTHER

Igloneige
Mariflex GE

#25
#26

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D-3

MATERIALS FOR SEALANT BLOCK

Name

Date Sheet #

GYPSUM

Aerostem

#1

CEMENT

Aqualight

#6

OTHER

Igloneige

#25

Mariflex GE

#26

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APPENDIX E

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